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Human Health Risk Assessment Prince Sultan Air Base, Saudi Arabia

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November 2000

Final Report
for November 1996 to December 1999

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14. ABSTRACT
A human health risk assessment (HRA) was completed to evaluate environmental samples (air, soil, and water) collected between 1996 and 1999, quantify risks to military personnel deployed to Prince Sultan Air Base (PSAB) based upon that data set, and identify environmental surveillance strengths and weaknesses. In addition to the HRA, a cursory review of air particulate matter was accomplished. This assessment did not evaluate nuclear, biological, or chemical weapon exposure. Particulate matter sample results are higher than the established national ambient air quality standards for the United States. Further evaluation is needed to better assess the potential health impact. Sample results were screened to identify contaminants of potential concern (COPC). During the screening process, the results were compared to the U.S. Environmental Protection Agency (USEPA), Region III Risk Based Concentration values. In total, 20 COPC were identified for further evaluation. The HRA performed on the 20 COPC resulted with risk values that are within the acceptable range considered safe by the USEPA. Although there are questions about the representativeness of the data, the results of the HRA suggest that personnel assigned and/or deployed to PSAB for up to 2 years should not have negative impact on their health due to the environment.

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ENVIRONMENTAL RISK ASSESSMENT
PRINCE SULTAN AIR BASE, SAUDI ARABIA

EXECUTIVE SUMMARY

U.S. Army, Center for Health Promotion and Preventive Medicine (CHPPM) and the U. S. Air Force, Air Force Institute for Environment, Safety and Occupational Health Risk Analysis (AFIERA) perform health risk assessments (HRAs) for deployed locations in Southwest Asia for the U. S. Central Command (CENTCOM). A HRA was completed to evaluate environmental samples (air, soil and water) collected between 1996 and 1999, quantify risks to military personnel deployed to Prince Sultan Air Base (PSAB) based upon that data set, and identify environmental surveillance strengths and weaknesses. In addition to the HRA, a cursory review of air particulate matter was accomplished. This assessment did not evaluate nuclear, biological, or chemical weapon exposure.

Particulate matter sample results are higher than the established national ambient air quality standards for the US. Although the particulate matter is high for the US standards, it is not necessarily high for the deployed region. <u>Further evaluation is needed to better assess the potential health impact</u>.

The risk assessment evaluated all potential exposure pathways using the environmental samples collected at PSAB between 1996 and 1999. USEPA Risk Assessment Guidance for Superfund (RAGS) was used as the framework for conducting this risk assessment. Although this guidance was written to address health risk associated with environmental restoration, the approach is valid to assess exposure, toxicity, and potential risks at deployed locations. This risk assessment is for both the carcinogenic and non-carcinogenic health risks to military and civilian adult personnel.

Sample results were screened to identify contaminants of potential concern (COPC). During the screening process, the results were compared to the United States Environmental Protection Agency (USEPA), Region III Risk Based Concentration (RBC) values. In total, 20 COPC were identified for further evaluation. The HRA performed on the 20 COPC resulted with risk values that are within the acceptable range considered safe by the USEPA. These risk estimates are based on very conservative estimates of exposure and toxicity and are likely to overestimate the actual risk. Risk assessment guidance does not provide comparison standards for particulate matter. Although there are questions about the representativeness of the data, <u>the results of the HRA suggest that personnel assigned and/or deployed to Prince Sultan Air Base for up to 2 years should not have negative impact on their health due to the environment</u>.

INTRODUCTION

Purpose

The purpose of this health risk assessment (HRA) is to evaluate environmental samples (air, soil and water) collected between 1996 and 1999, quantify risks to military personnel deployed to Prince Sultan Air Base (PSAB), and identify environmental surveillance strengths and weaknesses. Exposures identified as having a potential for producing an adverse health effect can be further evaluated through medical surveillance for exposed personnel.

U.S. Army, Center for Health Promotion and Preventive Medicine (CHPPM) and the U. S. Air Force, Air Force Institute for Environment, Safety and Occupational Health Risk Analysis (AFIERA) perform HRAs for deployed personnel to Southwest Asia for the U. S. Central Command (CENTCOM). This support to CENTCOM is provided for the project "Joint Environmental Surveillance Program for CENTCOM Area of Responsibility". This assessment does not evaluate nuclear, biological, or chemical weapon exposure.

Background

As part of force protection, coalition forces started occupying Prince Sultan Air Base (PSAB) in 1996 following the Khobar Towers bombing. PSAB is currently the home base for the 363rd Air Expeditionary Wing. Their mission is to enforce the no-fly zone in Southern Iraq, to be ready to defend against Iraqi aggression and to protect U.S. forces stationed in the region.

Prince Sultan AB is located approximately 100 km southeast of Riyadh inside a larger Saudi Air Base. Al Kharj is 17 km west of PSAB and Al Kharj East is 7 km east-southeast of PSAB. The population of the towns and industries present at Al Kharj East and Al Kharj West are not known. Reportedly, the Saudi military operates an incinerator on PSAB. PSAB is primarily manned with deployed personnel. The normal deployment duration for almost all personnel is 90 or 120 days with some variation to allow for overlap and transportation availability. There are also a few positions designated as permanent party with tour lengths of 1 or 2 years. The portion of the base occupied by U.S. and coalition forces consists of an operations area and the Friendly Forces Housing Complex[1] (FFHC). Prior to the opening of the FFHC in Feb 99, personnel were housed in a Tent City located in the operations area.

Environmental samples have been collected at PSAB since 1996. As part of the HRA all potential exposure pathways were evaluated by comparing sample results to the United States Environmental Protection Agency (USEPA) Region III Risk Based Concentration (established standards). When an analytical result was identified as being above the Region III Risk Based Concentration (RBC), it was identified as a chemical of potential concern (COPC). In total we identified 20 COPC, 8 are from air samples, 5 from non-potable water, and 7 from potable water. Soil data was reviewed and did not have any analytes above the USEPA Region III RBC. Samples for each COPC were statistically reviewed and risk estimates were calculated.

[1] FFHC – Name has changed to Coalition Forces Housing Complex and commonly referred to as Coalition Compound.

Climate

Saudi Arabia has a desert climate without marked seasons. Average rainfall is less than 5 inches per year. May through September is typically extremely hot and temperatures can reach 48°C (120°F). A northwesterly wind generally blows for much of the summer months and may cause sandstorms. A southerly shift in wind patterns during the winter months brings cool weather and rain from November through February with rain extending through April. Figure 1 presents the average number of days with rainfall and Figure 2 presents the annual average high temperatures.

Figure 1. Monthly Average of Days with Rainfall

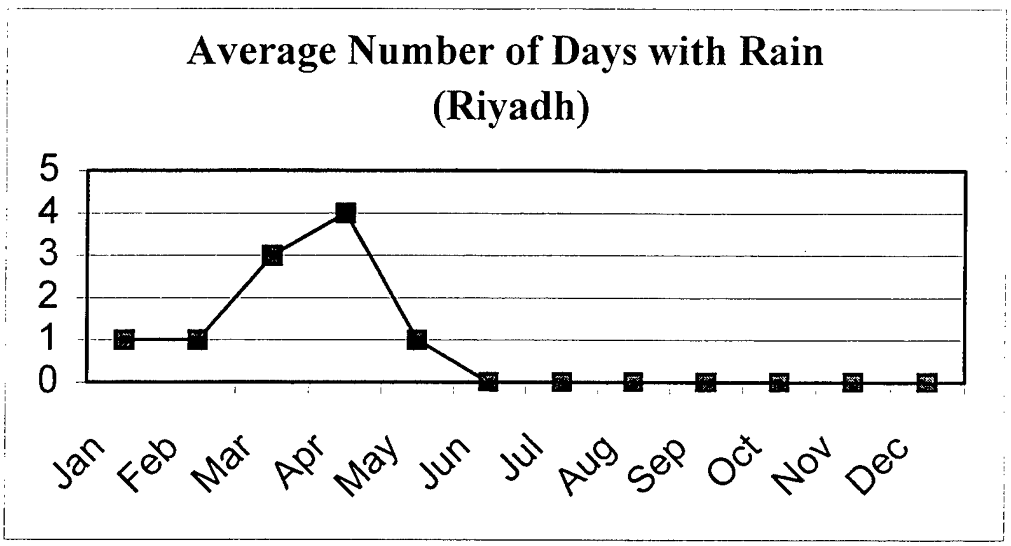
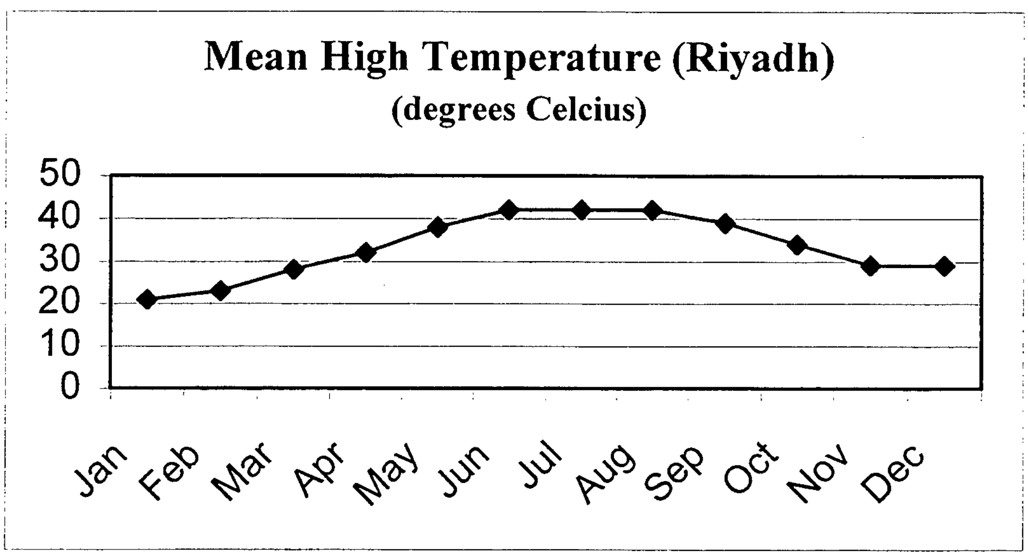


Figure 2. Monthly Average High Temperatures



RISK ASSESSMENT METHODOLOGY

USEPA Risk Assessment Guidance for Superfund (RAGS) was used as the framework for conducting this risk assessment. The USEPA RAGS is based on the National Research Council's four-step risk assessment paradigm which includes evaluating hazard identification, data quality, exposure intake, toxicity, and risk characterization. Our analysis is separated into four distinct phases and includes a discussion on the uncertainty and its effect on the risk estimate. Although these guidance documents have been written to address health risk associated with environmental restoration, the approach is valid to assess exposure, toxicity, and potential risks at deployed locations.

Data Collection and Evaluation

Data collection and evaluation answers the questions of what contaminants are present, where they are present, and in what concentrations. AFIERA's Environmental Analysis Division (AFIERA/RSE) provided the environmental sampling data for PSAB.

The data provided was limited and did not capture potential differences due to seasonal variation of environmental exposures. Ambient air samples were collected on three separate days between 26 Nov 96 and 10 Dec 96, representing the same season of the year. Actual sample location and local conditions were not provided. The majority of air samples (seven of nine) were collected on 10 Dec 96. Non-potable water samples were collected on two separate dates, 23 Oct 97 and 4 Aug 98. Potable water samples were collected on five separate days, from 7 Feb 97 to 8 Aug 98. All of the samples reviewed in this assessment were analyzed by AFIERA's Chemistry Division (AFIERA/SDC) or by their contract laboratories.

The sample results were summary in nature and did not include data packages with holding times, chromatograms, quality control information, or practical quantification limits. For the purposes of this assessment, we must assume that prior reviews have documented the data to be of adequate quality.

The sample results were screened to identify contaminants of potential concern (COPC). During the screening process, the results were compared to the United States Environmental Protection Agency (USEPA), Region III Risk Based Concentration (RBC) values. Region III RBC values were used per project guidance to maintain uniformity with previous health risk assessments completed for Southwest Asia. The initial screening identified 14 COPC.

After the screening was completed, each identified COPC was queried to determine its frequency of occurrence (number of times sampled compared to number of times above the RBC value). Contaminants with a frequency of less than 5 percent were eliminated. All of the COPC were above the 5 percent threshold.

All sample results for each COPC were evaluated including those below the analytical method detection limits. In accordance with RAGS, sample results indicating less than the sample detection limit were modified to half of the detection value, and samples indicating non-detect were given half of the lowest detection level. This resulted with 57 samples that were non-detect being above the RBC.

The COPC were sorted by type of sample (ambient air, soil, water-potable, and water-non-potable). Some of the COPC are repeated in different media boosting the total number to 20 COPC. The sample results for each COPC were statistically analyzed to determine if the data distribution fit better to a normal or log normal distribution. The 95th percent upper confidence limit (95% UCL) was calculated based on the type of best fit. The 95% UCL value was used as the reasonable maximum exposure (RME) concentration to derive risk numbers. The RME is used to be protective; ensuring that high end of intake/dose is captured. Using the RME results with a conservative estimate of risk. Whenever the 95% UCL exceeded the maximum sample result, the maximum sample result was used as the RME. The central tendency (CT) values were also calculated to derive comparative risk numbers. The COPC are listed in Table 1.

Table 1. Chemicals of Potential Concern

Num	CAS	COPC	Media	RBC	Unit	Max	95% UCL	CT
1	107028	Acrolein	A	0.02	μg/m^3	5.7	2.466	1.5
2	71432	Benzene	A	0.22	μg/m^3	4.2	2.193	1.248
3	50328	Benzo(a)pyrene	A	0.002	μg/m^3	0.002	0.001	0.001
4	319857	beta-BHC	A	0.0035	μg/m^3	0.0038	0.002	0.001
5	56235	Carbon Tetrachloride	A	0.12	μg/m^3	1.2	0.869	0.684
6	67663	Chloroform	A	0.07	μg/m^3	0.66	0.417	0.312
7	74873	Chloromethane	A	1	μg/m^3	2.5	2.5	0.889
8	75092	Methylene Chloride	A	3.8	μg/m^3	210	210	49.5
9	7440382	Arsenic	N	0.04	μg/L	7.1	7.1	5.1
10	75274	Bromodichloromethane	N	0.17	μg/L	41.5	41.5	14
11	75252	Bromoform	N	2.3	μg/L	23.9	23.9	8.1
12	124481	Chlorodibromomethane	N	0.13	μg/L	34.6	34.6	11.7
13	67663	Chloroform	N	0.15	μg/L	347.4	347.4	116
14	75354	1,1-Dichloroethene	P	0.04	μg/L	0.5	0.369	0.261
15	117817	Bis(2-ethylhexyl)phthalate	P	4.8	μg/L	5.7	2.324	1.3
16	75274	Bromodichloromethane	P	0.17	μg/L	20.9	13.088	2.53
17	75252	Bromoform	P	2.3	μg/L	4.3	2.703	1.678
18	56235	Carbon Tetrachloride	P	0.16	μg/L	0.8	0.696	0.317
19	124481	Chlorodibromomethane	P	0.13	μg/L	10.7	6.873	1.67
20	67663	Chloroform	P	0.15	μg/L	57	57	6.51

Note: A = Ambient Air, N = Non-potable Water, P = Potable Drinking Water

The contaminants found in the air samples are typical of maintenance activities and industrial operations (e.g. painting, production/combustion of plastics, and fuel combustion) and pesticide application/production. The majority of contaminants found in both potable and non-potable water samples are typical chlorination by-products.

Exposure Assessment

Exposure assessment is the determination or estimation, qualitatively or quantitatively, of the magnitude, frequency, duration, and route of exposure. Exposure is defined as the contact of an organism with a chemical or physical agent.

The exposure assessment is a four-step process:

Step 1: Characterize the Exposure Setting
Step 2: Identify Exposure Pathways
Step 3. Quantify Exposure
Step 4. Verify Completed Pathway

Step 1: Characterize the Exposure Setting

The exposure setting for this assessment was military and contractor personnel residing on-base. Major Gooden (AFIERA/RSEW) provided a background setting for water distribution. The sampling occurred during the time period when personnel lived in Tent City. Water for consumptive use consisted of bottled drinking water and plumbed potable water at the Dining Hall. Water used for personal sanitary purposes was bulk non-potable water. Assumptions made for the exposure assessment include: ambient air samples are considered to be background levels for this population, base population drank only designated drinking water, and the base population used plumbed non-potable drinking water for personal hygiene and sanitary activities (e.g. showering, bathing, and flushing). Daily exposure periods vary on the type of exposure scenario selected (e.g. residential, commercial, industrial, agricultural, or recreational). For this HRA, a residential scenario was selected to account for a maximum daily exposure period of 24 hours.

An exposure duration of two years, the maximum time on station, was used. Children are currently not on station at PSAB and no risk calculations were performed for children. The majority of personnel are deployed with nominal deployment duration of 90 – 120 days. Key positions are filled with permanent party personnel on 1 or 2 year-tours. We assumed a worst case scenario of 350 days per year exposure, which is the USEPA default value (USEPA, 1989). Since this HRA is conservative with respect to approach and calculations, the USEPA default value of 15 days away from the site is used in-lieu of more site-specific data that may be closer to 335 days accounting for annual leave.

Step 2: Identify Exposure Pathways

Domestic uses of water, consumption and bathing/showering, were included in this HRA for possible exposure pathways. The routes of exposure considered were ingestion, inhalation from showering, and dermal absorption from showering. Other pathways from domestic uses of water were not included (e.g. washing clothes, flushing, and cooking). The understanding of the plumbing at PSAB during the sampling period indicates that residences and maintenance areas had plumbed non-potable water. Since that time, the FFHC has been developed and now all residents are living in the FFHC and have plumbed potable water. In order to standardize the potential exposure during showering, the non-potable water contaminants were used to determine dermal and inhalation exposure.

Ambient air sample results were used for assessing the inhalation hazard and based on a 24-hours per day exposure duration. Soil sample results were all below the USEPA Region III RBC standards.

Step 3. Quantify Exposure

A tiered approach to risk assessment was followed as shown in Figure 3. A simple screening was conducted comparing sample results to RBC values. In some cases, such as potential exposures during showering, the USEPA Region III RBCs were used as input values in USEPA Region IX calculations. This provides more conservative estimate of risk. Tier I screening indicated most of the analytes are below their respective RBCs. COPC above the RBCs were further evaluated using USEPA RAGS.

In order to quantify exposures, it is necessary to make assumptions and assign values to these assumptions. A USEPA risk assessment usually includes an estimation of intake based on both the average concentration and a concentration correlating to the 95th UCL of the mean. Since the 95th UCL approach is more conservative and likely overestimates risk, it was used to estimate intake. Attachment 1 presents a summary of all the COPC (total number of analytes, frequency, media type, RBC value, max value, determination of the COPC sample distribution is normally or lognormally distributed (determined using the Shapiro and Wilk test).

In the absence of site-specific data, USEPA recommends default values based on scientific studies and professional judgment. Table 2 provides the default exposure values used for inhalation and ingestion routes. With the exception of the upper limit for drinking water consumption, we have designated each as either a site-specific (SS) value or USEPA default (EPA). The upper limit for drinking water was taken from the Military Specific Exposure Factors (MSEF) study. Table 3 provides the default exposure values used for dermal exposure. Dermal exposure is based on skin surface area.

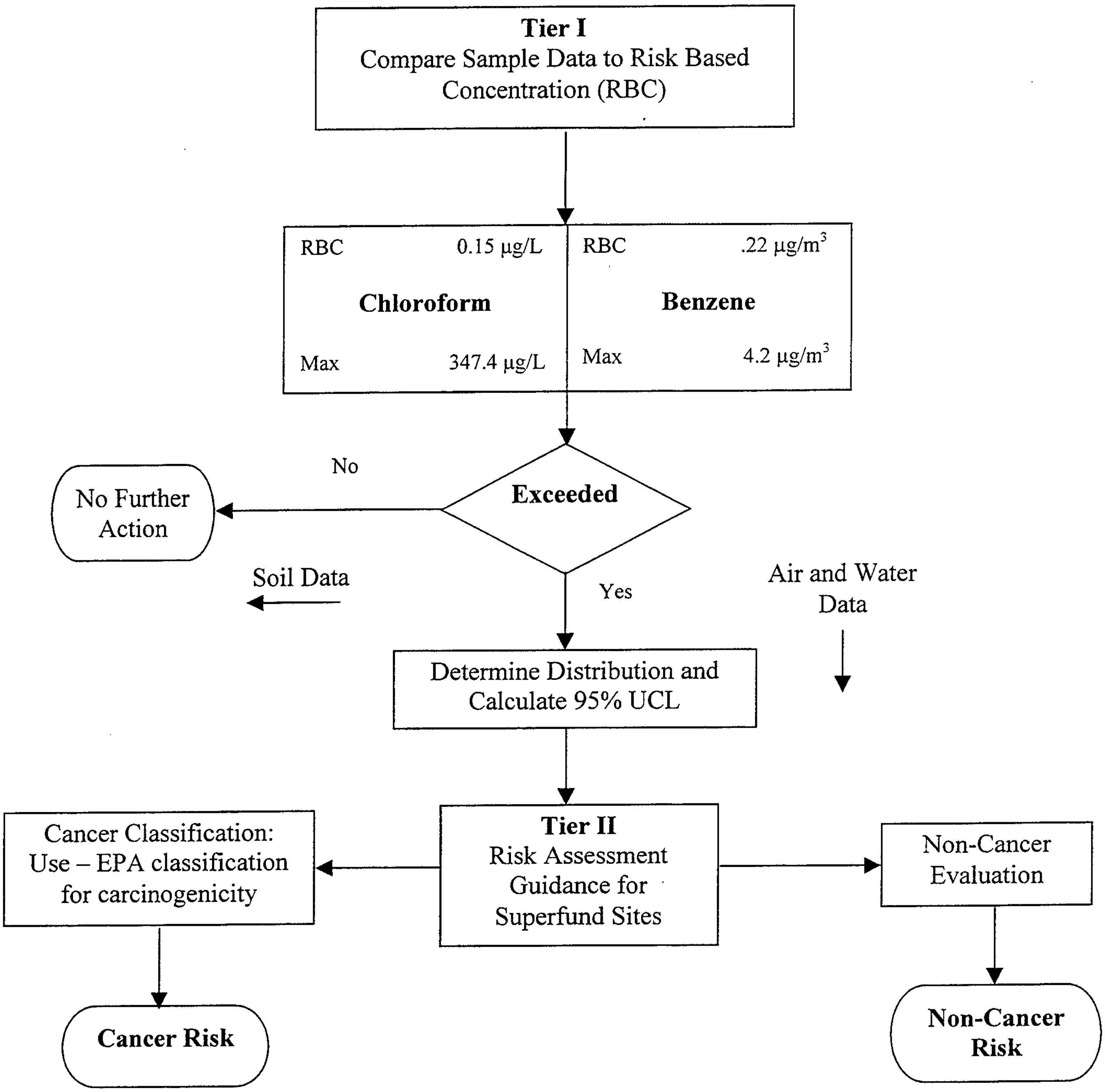
Table 2. Exposure Parameters for Inhalation and Ingestion

Exposure Scenario	Exposure Pathway	Daily Intake Rate	Exposure Frequency	Exposure Duration	Body Weight
Residential	Ingestion of Potable Water	2 liters (USEPA) 11.4 liters (MSEF)	350 days/yr (USEPA)	2 years (SS)	70 kg (USEPA)
	Inhalation of Contaminants (Showering)	20 meters^3/day (USEPA)	365 days/yr (SS)	2 years (SS)	70 kg (USEPA)

Table 3. Exposure Parameters for Dermal

		Skin Surface Area			
Residential	Dermal Absorption (Showering)	23000 cm^2 (USEPA)	365 days/yr (SS)	2 years (SS)	70 kg (USEPA)
		Bath Duration			
		0.2 hr (USEPA)			

Figure 3. Tiered Approach to Risk Assessment.



There are four basic equations used to calculate intake and dose: 1) drinking water ingestion, 2) non-potable water – shower inhalation, 3) non-potable water – shower dermal, and 4) ambient air inhalation. The plumbed water is assumed to be from non-potable water sources only.

Equation 1 is used to calculate the average daily intake from ingestion of contaminants in the drinking water. The exposure assumption values used to calculate the average dose from ingestion of drinking water contaminants are shown in Table 2. The central tendency (CT), or average ingestion rate was assumed to be 2 L/day, with a maximum (RME) ingestion rate of 11.4 L/day. The average ingestion rate was selected because it is the USEPA default long-term ingestion rate for adults, and is based on the average consumption rate of water for adults performing normal activities. The maximum ingestion rate was selected because it represents an increased consumption of water due to heavy activities and/or increased temperature during the workday.

Equation 1. Residential Exposure – Drinking Water, Ingestion

$$I = CW \times \left(\frac{CR \times EF \times ED}{BW} \right) \times \frac{1}{AT}$$

where:

I	=	intake (mg/kg body weight per day)
CW	=	Chemical concentration in water (ug/L)
CR	=	Contact rate (liters/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (usually expressed in years)
BW	=	Body weight (kg)
AT	=	Averaging time (in days; for carcinogens 70 years x 365 days/year, for non-carcinogens ED x 365 days/year)

Equation 2 is used to calculate the average daily intake from inhalation of volatilized airborne contaminants from plumbed water. The exposure assumption values used to calculate the average dose from airborne contaminants are shown in Table 2.

Equation 2. Residential Exposure – Non-Potable Water, Showering -- Inhalation

$$I = CA \times \left(\frac{IR \times EF \times ED \times SD}{BW} \right) \times \frac{1}{AT}$$

where:

I	=	Intake (mg/kg [body weight] per day)
CA	=	Chemical concentration in air (mg/m3)
IR	=	Inhalation rate (m3/min)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (usually expressed in years)
BW	=	Body weight (kg)
AT	=	Averaging time (in days; for carcinogens 70 years x 365 days/year, for non-carcinogens ED x 365 days/year)
SD	=	Shower duration (minutes)

Equation 3 is used to calculate the average daily dose resulting from dermal contact with plumbed water. The exposure assumption values used to calculate the average dose from dermal contact with contaminants are shown in Table 3.

Equation 3. Residential Exposure – Non-Potable Water, Showering -- Dermal

$$AD = CW \times \left(\frac{SA \times pK \times ET \times EF \times ED \times CF}{BW} \right) \times \frac{1}{AT}$$

where:

AD	=	Absorbed Dose (mg/kg body weight per day)
CW	=	Chemical concentration in water (mg/L)
SA	=	Skin surface area available for contact (cm^2)
PK	=	Chemical-specific dermal permeability constant (cm/hr)
ET	=	Exposure time (hours/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (usually expressed in years)
CF	=	Volumetric conversion factor for water (1 liter/1000cm^3)
BW	=	Body weight (kg)
AT	=	Averaging time (in days; for carcinogens 70 years x 365 days/year, for non-carcinogens ED x 365 days/year)

Equation 4 is used to calculate the average daily intake from inhalation of airborne contaminants. The exposure assumption values used to calculate the average dose from airborne contaminants are shown in Table 2. The central tendency (CT), or average inhalation rate was assumed to be 15.3 m^3/day, with a maximum (RME) inhalation rate of 20 m^3/day. The average inhalation rate was selected because it is the default long-term inhalation rate for adults, and is based on the average breathing rate of adults performing normal activities. The maximum inhalation rate was selected because it represents an increased inhalation rate due to heavy activities during the workday (USEPA, 1997).

Equation 4. Residential Exposure – Inhalation of Airborne Chemicals

$$I = CA \times \left(\frac{IR \times ET \times EF \times ED}{BW} \right) \times \frac{1}{AT}$$

where:

I	=	Intake (mg/kg [body weight] per day)
CA	=	Chemical concentration in Air (mg/m3)
IR	=	Inhalation rate (m3/hour)
ET	=	Exposure time (hours/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (usually expressed in years)
BW	=	Body weight (kg)
AT	=	Averaging time (in days; for carcinogens 70 years x 365 days/year, for non-carcinogens ED x 365 days/year)

Step 4. Verify Completed Pathway

The evaluation and verification of the pathway is difficult to prove. There are many variables that impact the completed pathway. A conceptual site model was developed for PSAB and is shown below as Figure 4.

There are multiple sources of contamination at any given location, but there are not always completed pathways. Due to limited nature of the sampling data, many of the potential pathways can not be evaluated. This assessment takes a simplistic approach for evaluating the exposure pathway. We know that the personnel assigned at this location are working and living in the same general area and therefore assume they are breathing the same air as captured by ambient air samplers. Likewise, the individuals have virtually no choice when bathing/showering and therefore are using the supplied non-potable water. Drinking water does leave some ambiguity, but it is assumed that the majority of water intake comes from drinking bottled water because the only potable water source other than bottled water was the dining hall. Potable water is now being supplied to many locations including the FFHC allowing for a much higher percentage of consumption of plumbed potable water.

Toxicity Assessment

The toxicity assessment is divided between cancer and non-cancer health effects resulting from exposures. Cancer effects are evaluated using a slope factor and weight-of-evidence and are calculated based on actual exposure duration. It is important to note that the slope factors are based on the understanding that no exposure is risk free and, therefore, is without a health effect threshold. The weight-of-evidence looks at the likelihood of an agent being a human carcinogen. The likelihood is determined by evidence presented in literature from human and laboratory animal data. Each chemical is assigned a classification code from A through E (A – known human carcinogen and E – evidence of noncarcinogenicty). The slope factor quantitatively defines the relationship of dose and response.

Most often, the non-cancer effect compares exposure levels to a reference dose (RfD). The reference dose is further broken down depending on the type of exposure such as oral or inhalation as well as the duration of exposure. The USEPA is often concerned with lifetime exposures and most often uses the chronic RfD values. The chronic RfD is defined as an estimate of a daily exposure level for a human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime.

The USEPA has also developed subchronic RfDs (RfD_s) for shorter-term exposures. The RfD_s is used for exposure duration of 2 weeks to 7 years and therefore ideal for the health risk assessments being conducted for southwest Asia including PSAB. However, because we are using USEPA Region III Risk Based Concentrations (RBCs) and Region III does not have established subchronic RfDs, we are using the chronic RfDs.

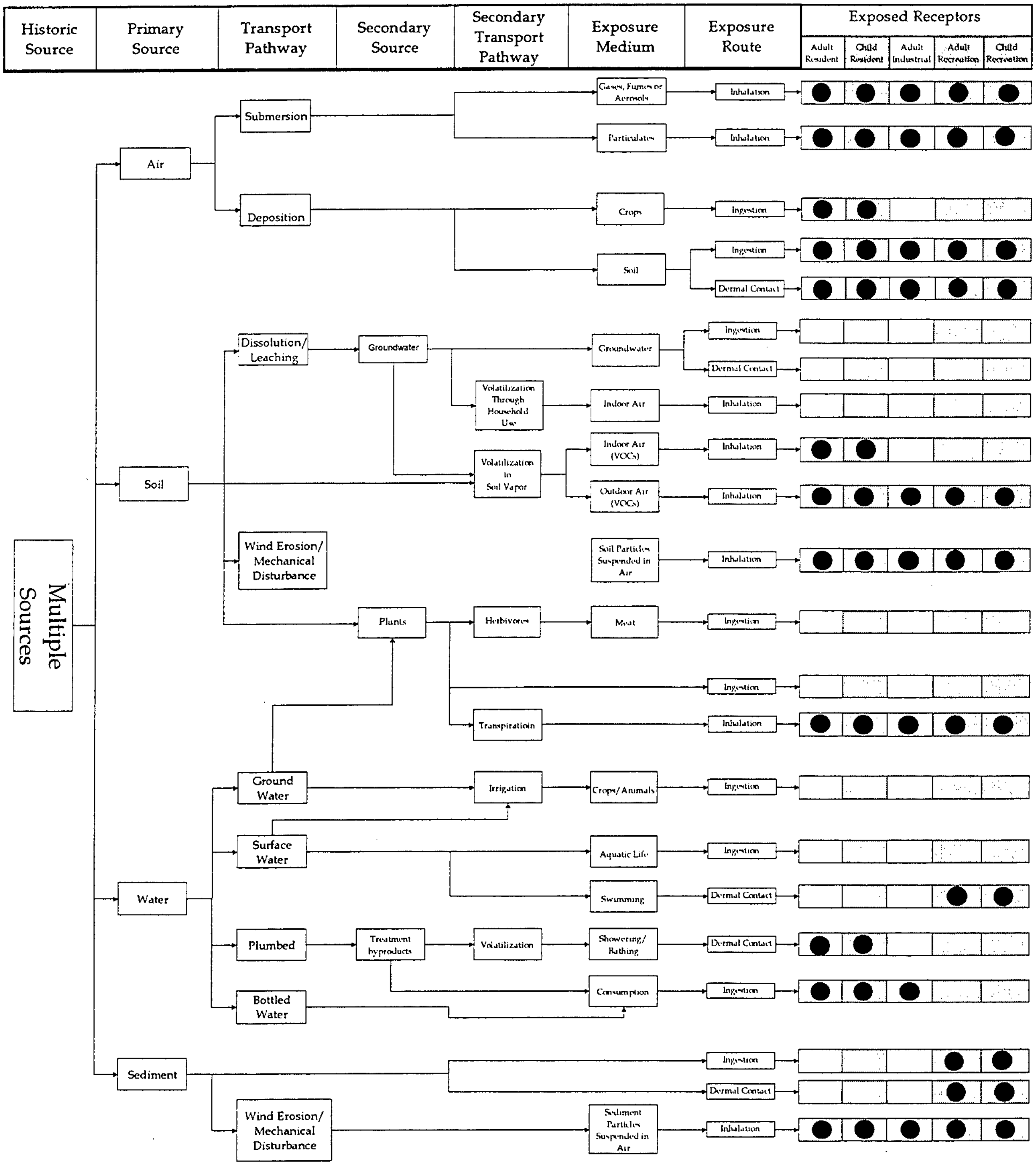
Toxicity Values

The toxicity assessment provides information on the potential health effects. The toxicity values are based on oral, dermal, and inhalation exposure pathways. Values for reference doses, reference concentrations, cancer slope and unit risk values have been derived from a variety of sources. The most acceptable and verifiable values are derived from US EPA's Integrated Risk Information System (IRIS).

To be cited in IRIS, there must exist a body of knowledge regarding a given chemical. For non-cancer studies, it is important to have chronic, multigenerational, developmental and reproductive studies. Human data usually take precedence over animal bioassay data. Cancer studies include human epidemiology studies, rodent bioassays, and vitro assays that might shed light on the mode of action for carcinogenesis. Non-verifiability in IRIS is usually due to a deficiency in the scientific data required for making quantitative analyses.

Toxicity values represent "safe" levels of exposure to avoid cancer and non-cancer effects. Region III RBC tables are a compilation of US EPA IRIS and Health Effects Assessment Summary Tables (HEAST) and recent EPA-NCEA (National Center for Environmental Assessment) provisional toxicity values. Table 4 identifies the COPC, the weight of evidence characterization of carcinogenicity, toxicity values used, and the source of value.

Figure 4. Conceptual Site Model for Prince Sultan Air Base



Risk Characterization

The risk characterization phase integrates information from the other three phases of the risk assessment and forms an overall conclusion about the risk. Steps for quantifying the carcinogenic risk or non-carcinogenic hazard quotient are applied to each exposure pathway and analyzed.

Carcinogenic Effects

For carcinogens, risk estimators are expressed as the excess incremental probability, above background cancer rates, of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen. The USEPA, within the Superfund Program, has determined the acceptable range of excess cancer to be 1×10^{-4} to 1×10^{-6} (i.e. the probability of one excess cancer in a population between 10,000 to 1,000,000). USEPA guidance assumes a linear dose-response relationship due to the relatively low exposure levels found at Superfund sites; therefore, the slope factor is a constant, and the risk will be directly related to intake. Under this assumption, the linear low-dose equation for a single chemical is described below.

Equation 5. Carcinogenic Risk

$$\left[\text{Risk} = \quad \text{LADD} \times \text{SF} \right]$$

Where:

Risk = A unit-less probability
LADD = Lifetime average daily dose over 70 years (mg/kg-day)
SF = Slope factor, the carcinogenic toxicity value $(\text{mg/kg-day})^{-1}$

The risk calculated for each chemical of concern is next summed together to generate an estimate of total risk per exposure pathway.

Equation 6. Total Risk

$$\left[\text{Total Risk} = \quad Risk_1 + Risk_2 + Risk_3 + \ldots + Risk_i \right]$$

Where:

Total Risk = the total cancer risk, expressed as a unit-less probability
$Risk_i$ = the calculated risk for each chemical of concern

Table 4. Toxicity Factors for COPC

Reference Doses and Carcinogenic Potency Slope Factors										
			Sources: I = IRIS; E = EPA-NCEA provisional value; H = HEAST; A = HEAST Alternate; O = other; W = Withdrawn from IRIS or HEAST							
Contaminant	***CAS***	***EPA Cancer Class.***	***Oral RfDo mg/kg/d***	***Source of data***	***Oral Slope Factor CSFo kg·d/mg***	***Source of data***	***Inhalation RfDi mg/kg/d***	***Source of data***	***Inhalation Slope Factor CSFi kg·d/mg***	***Source of data***
1,1-	75354	C	9.00E-03	I	6.00E-01	I			1.75E-01	I
Acrolei	107028	C	2.00E-02	H			5.70E-06	I		
Arsenic	7440382	A	3.00E-04	I	1.50E+00	I			1.51E+01	I
Benzene	71432	A	3.00E-03	E	2.90E-02	I	1.70E-03	E	2.90E-02	I
Benzo(a)pyren	50328	B2			7.30E+00	I			3.10E+00	E
Beta-BHC	319857	C	1.80E+00	I			1.80E+00	I		
Bis(2-	117817	B2	2.00E-02	I	1.40E-02	I			1.40E-02	E
Bromodichlorometha	75274	B2	2.00E-02	I	6.20E-02	I				
Bromofor	75252	B2	2.00E-02	I	7.90E-03	I			3.90E-03	I
Carbon	56235	B2	7.00E-04	I	1.30E-01	I	5.71E-04	E	5.30E-02	I
Chlorodibromometha	124481	C	2.00E-02	I	8.40E-02	I				
Chlorofor	67663	B2	1.00E-02	I	6.10E-03	I	8.60E-05	E	8.10E-02	I
Chloromethan	74873	C			1.30E-02	H			6.00E-03	H
Methylene	75092	B2	6.00E-02	I	7.50E-03	I	8.60E-01	H	1.65E-03	I

US EPA Cancer Classification Scheme:

A: Human carcinogen: sufficient evidence from epidemiologic studies to support a causal association between exposure and cancer.

B: Probable Human Carcinogen: weight of evidence of human carcinogenicity based on epidemiologic studies is limited; agents for which weight of evidence of carcinogenicity based on animal studies is sufficient.

Two subgroups:

B1: limited evidence of carcinogenicity from epidemiologic studies.

B2: Sufficient evidence from animal studies; inadequate evidence or no data from epidemiologic studies

C: Possible Human Carcinogen: limited evidence of carcinogenicity in animals in the absence of human data.

Reference Concentration (RfC): An estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious non-cancer effects during a lifetime.

Reference Dose (RfD): An estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.

Cancer Slope Factor (CSF): The slope of the dose-response curve in the low-dose region. When low-dose linearity cannot be assumed, the slope factor is the slope of the straight line from 0 dose (and 0 excess risk) to the dose at 1% excess risk. An upper bound on this slope is usually used instead of the slope itself. The units of the slope factor are usually expressed as 1/(mg/kg-day).

Noncarcinogenic Effects

The measure used to describe the potential for noncarcinogenic toxicity to occur in an individual is not expressed as a probability, but is a comparison of the exposure (intake) with a reference dose. This ratio of exposure to toxicity is called the noncancer hazard quotient.

Equation 7. Noncarcinogenic Hazard Quotient

$$\left[\text{Noncancer Hazard Quotient}^* = E/RfD \right]$$

Where:

$E =$ Exposure level or chronic daily dose (CDD)
$RfD =$ Reference dose

*E *And RfD must be expressed in the same units and represent the same exposure period.*

The RfD is the US EPA's preferred oral toxicity value for noncancer effects. It is defined as an estimate of a daily exposure level for the human population, including sensitive subpopulations (with an order of magnitude for uncertainty) that is likely to be without an appreciable risk of deleterious effects during a lifetime. If the exposure level exceeds the toxicity value (ratio greater than 1), there may be some concern for potential adverse health effects. The level of concern does not increase linearly as the RfD is approached or exceeded because RfDs do not have equal accuracy or precision nor are they based on the same severity of toxic effects.

Similar to calculating total risk, the total potential for noncancer effects is determined by summing the hazard quotients for each chemical of concern, resulting in a hazard index (also described in Exposure Assessment, Step 3).

Equation 8. Hazard Index

$$\left[HI^* = E_1/RfD_1 + E_2/RfD_2 + \ldots .. + E_i/RfD_i \right]$$

Where:

$E_i =$ Exposure level (or intake) for the i^{th} toxicant
$RfD_i =$ Reference dose for the i^{th} toxicant

*E *And RfD must be expressed in the same units and represent the same exposure period.*

If the hazard index exceeds unity (1), the analyst must closely examine the target organs involved. If different target organs are affected, the hazard index should be recalculated to group those chemicals that may elicit like responses.

Risk Calculations

Using the principles described above, the carcinogenic risks and non-cancer hazard indices were calculated accounting for exposures to drinking water ingestion, inhalation from showering, and dermal absorption from showering. The calculation for cancer risk is based on a 2 year exposure, but can be extrapolated to any period since the cancer risk is directly related to intake. For non-cancer effects, the hazard quotient is the same, regardless of duration.

In the Superfund program, USEPA tries to manage risks in the one in ten thousand to one in one million range. Below one in one million, the risk is considered negligible; above one in ten thousand, some action is usually required. The USEPA preference is for risk numbers to be near the more protective end of the range (one in one million). For PSAB, the cancer risk estimates for exposure to water and ambient air is within the USEPA's target range. Table 5 shows the cancer risks associated with exposure medium at PSAB, for a 2 year duration, for both 2-L/day and 11.4-L/Day ingestion of drinking water, and comparison of the CT and RME values.

For the purposes of this document, we used toxicity values from the US EPA Region 3 RBC table. This table includes the typical sources that are used for risk assessments (IRIS, NCEA Health Effects Assessment Summary Tables (HEAST) and ATSDR). For non-cancer effects, the RfD, RfC, and MRLs are all derived in approximately the same way: NOAEL (or LOAEL) is determined (preferably from human data, but more usually from animal studies) and is divided by uncertainty factors. These uncertainty factors represent the uncertainty in extrapolating from animals to humans; from a LOAEL to a NOAEL; from subchronic to chronic studies; and to account for sensitive subpopulations. Table 6 summarizes the non-cancer toxicity values for the chemicals of potential concern at PSAB.

Table 5. Associated Cancer Risk

Summary of Cancer Risks; Ingesting 2 and 11.4 Liters of Drinking Water per Day				
	RME		CT	
Exposure Route	*Cancer Risk 2 Liters/Day*	*Cancer Risk 11.4 Liters/Day*	*Cancer Risk 2 Liters/Day*	*Cancer Risk 11.4 Liters/Day*
Adult: Drinking Water -- Ingestion, 2 & 5 Liters per Day	1.72E-06	9.78E-06	4.62E-07	2.63E-06
Adult: Drinking Water -- Showering, Inhalation	6.32E-05	6.32E-05	1.43E-06	1.43E-06
Adult: Drinking Water -- Showering, Dermal	1.92E-06	1.92E-06	6.70E-07	6.70E-07
Adult: Residential -- Ambient Air	4.15E-06	4.15E-06	1.53E-06	1.53E-06
Adult: Residential -- Soil -- Dermal				
Totals	**7.10E-05**	**7.90E-05**	**4.09E-06**	**6.27E-06**

A Hazard Index (HI) was calculated using the traditionally defined RfDs for each chemical. The HI for each exposure route and summed total are less than unity and therefore would not be evaluated any further within the United States. The HI for each exposure route is shown in Table 6.

Table 6. Systemic Hazard Quotient for Noncancer Risk

Summary of Noncancer Hazard Indices		
	RME	**CT**
Exposure Route	***NonCancer Systemic Hazard Index HI***	***NonCancer Systemic Hazard Index HI***
Adult; Drinking Water -- Ingestion, 2 Liters per Day	3.07E-05	6.04E-06
Adult; Drinking Water -- Showering, Inhalation	2.92E-09	2.79E-05
Adult; Drinking Water -- Showering, Dermal	1.84E-05	6.17E-06
Adult; Residential -- Ambient Air	5.16E-02	1.22E-02
Adult; Residential -- Soil -- Dermal		
Totals	**5.17E-02**	**1.22E-02**

UNCERTAINTY

Risk assessments are estimations of what might occur under certain conditions, provided there is both a hazard present and exposure occurs. These estimations are based on data, assumptions, and models that contain inherent uncertainties. Uncertainties may contribute to an overestimation or underestimation of the true risk and decreases confidence in the calculated risk. This section will address the uncertainties present within each of the four-part risk assessment process.

Data Collection and Evaluation

Uncertainty is inherent with environmental sampling due to the uneven distribution of chemicals in the environmental media over space and time. There are also inherent uncertainties associated with the collection, analytical preparation, and measurement of samples. The PSAB results reviewed for this report were summary in nature and did not include data packages with holding times, chromatograms, quality control information, or practical quantification limits. For the purposes of this assessment, we must assume that prior reviews have documented the data to be of adequate quality. The uncertainty of this data gap on the outcome of risk is unknown.

The sample data provided for PSAB does not have sample specific information other than the location, date, and result. This contributes to the uncertainty about the relationship of data to exposed population and sources. For example, the air sampling data had a few contaminants with elevated results indicating an industrial operation/process may have been occurring nearby. Without a written description of what was occurring during the sample collection period, it becomes very difficult to identify potential sources of these elevated results.

There is a general assumption that the samples collected are similar to each other with respect to area being sampled. With any risk assessment, the site-specific data needs to be representative of the anticipated environmental exposures. In this case, we're attempting to evaluate daily average exposures that are likely to occur. The sample data collected is not spanning the normal 4 quarters of the year or even the typical 3 seasons of the region. The data therefore may not be representative of the actual exposures associated with the site. Year-round air and water sampling data to account for seasonal variations is needed. Without seasonal data, the representativeness of the data is questionable. The uncertainty of this data gap on the outcome of risk is unknown.

In addition to the lack of seasonal data, there were not enough media specific samples collected. Typically, the greater the number of samples collected, the greater the confidence there is with the data. With higher confidence, it is easier to eliminate erroneous sample results. This is an issue of pervasiveness, where a COPC is identified as being above the RBC more than 5% of the time sampled. However, when less than 20 samples are collected and one sample results in a COPC, it would be inappropriate to eliminate that COPC from further evaluation. This then requires the inclusion of potentially erroneous contaminants in the risk assessment making it more convoluted and less focused on the primary contaminants. The uncertainty of adding erroneous contaminants can only overestimate the risk.

All sample results for each COPC were evaluated including those below the analytical method detection limits. In accordance with RAGS, sample results indicating less than the sample detection limit were modified to half of the detection value, and samples indicating non-detect were given half of the lowest detection level. This resulted with many of the non-detect samples being above the RBC. The uncertainty of this probably overestimates the overall risk.

The majority of the analytical results are non-detects or less than the detection limit. If these results were converted from a less-than a detection limit value to an actual number (half of the detection limit), many of the analytical results would be above the RBC. This indicates the analytical detection limit was not low enough and can be eliminating contaminants that should be identified as COPC. The uncertainty of this probably underestimates the risk.

Based on the USEPA RAGS methodology, the reasonable maximum exposure (RME) concentration is used to derive risk numbers. The RME is used to be protective; ensuring that high end of intake/dose is captured. The actual intake/dose that is received by personnel assigned to PSAB is probably somewhere between the mean and RME concentration and therefore using the RME result will overestimate the potential risk.

In all, there were 6432 analytical results provided for this HRA. However, because only Region III RBCs were used to generate risk numbers, only 3763 analytes were actually screened. This is because of all the analytes provided, 2669 did not have an associated RBC with it. The uncertainty of this can only underestimate the risk.

Exposure Assessment

Air sampling data indicates the presence of contaminants that should is not expected to be present at background levels. The potential sources of these contaminants are unknown as is the exact sample location and proximity to on- and off-base industrial operations.

Showering is also a source of uncertainty. The actual inhalation exposure to contaminants from showering and bathing are unknown since the base had different water supplies. At one point, all personnel where showering in tents using non-potable water, then some personnel moved to hard facilities with potable plumbed water, and then all personnel moved into the FFHC. It is still not certain when all of the assigned personnel were using potable water for showering versus the plumbed non-potable water. The risk was calculated using the non-potable analytical data since it is the most conservative and therefore probably overestimates the potential risk. Additionally, we have assumed inhalation of VOCs while showering, but do not have measured data to support the concentrations we generated using Henry's Law constants—the impact on the assessment is unknown.

Dermal absorption also introduces uncertainty because we assumed the VOCs stay in the water to contact the skin, and are then absorbed into the body. However, because we have assumed volatilization previously, it is unlikely the concentrations we calculated would be achieved in both media. As a result, the risk is probably overestimated.

Water exposure data gaps contribute to the uncertainty of the calculated risk numbers. The base supply of drinking water had multiple sources. Water was trucked in as potable and non-potable water and bottled water was purchased from a local vendor. Both potable and non-potable samples had contaminants that are known to be associated with disinfection of the drinking water. The assumption for this HRA is the majority of the consumed water is from bottled water. Bottled water chemical analysis is sparse. If the bottled water has similar chlorination byproducts the risk calculations may appropriately estimate the risk from ingestion of drinking water, but most likely the chlorination byproducts will not be present. Because the drinking water issue was not stratified, the RME risk number is based on the plumbed potable water results. If the bottled water does not have COPC, the uncertainty with using the COPC from the plumbed potable water is most likely to overestimate the potential risk.

Toxicity Assessment

Toxicity values are based primarily on human and animal studies. The studies provide information on the dose where the lowest observed adverse effect level (LOAEL) or no observed adverse effect level (NOAEL) is generated experimentally in response to a known exposure over a defined period of time. Safety factors are then applied to the LOAEL or NOAEL to yield a reference dose (RfD, oral) or reference concentration (RfC, inhalation) that is considered the safe threshold for human exposure. Safety factors can range from 1 to 10,000, so there can be a large degree of uncertainty about the "safe dose" for humans. In general, these safety factors are protective for sensitive sub-populations and therefore tend to be very conservative. The built in safety factors will most likely result in an overestimation of risk.

The USEPA has also developed subchronic RfDs (RfD_s) for shorter-term exposures. The RfD_s is used for exposure duration of 2 weeks to 7 years and therefore ideal for the health risk assessments being conducted for southwest Asia including PSAB. However, since we are bound to use USEPA Region III RBCs, which do not specify sub-chronic RfDs, chronic RfDs are used. This will result with overestimated risk.

Risk Characterization

In order to calculate the inhalation risk of airborne contaminants while showering, we used the USEPA Region IX exposure model. The uncertainty with using the Region IX model is not determinable.

AIR QUALITY

The air quality is another health concern for deployed personnel in this region. Of particular interest is particulate matter (PM). The USEPA has established national ambient air quality standards (NAAQS) for PM. Specifically, the USEPA is concerned with PM-2.5 as well as PM-10 (particulate matter having a nominal aerodynamic diameter less than or equal to 2.5 and 10 microns, respectively).

Currently there is no data available from Prince Sultan Air Base for $PM_{2.5}$, but there is data for PM_{10} and TSP (total suspended particulate). Approximately 50 samples were collected from 27 Oct 96 through 22 Dec 96. A summary of the data is presented below in Table 7.

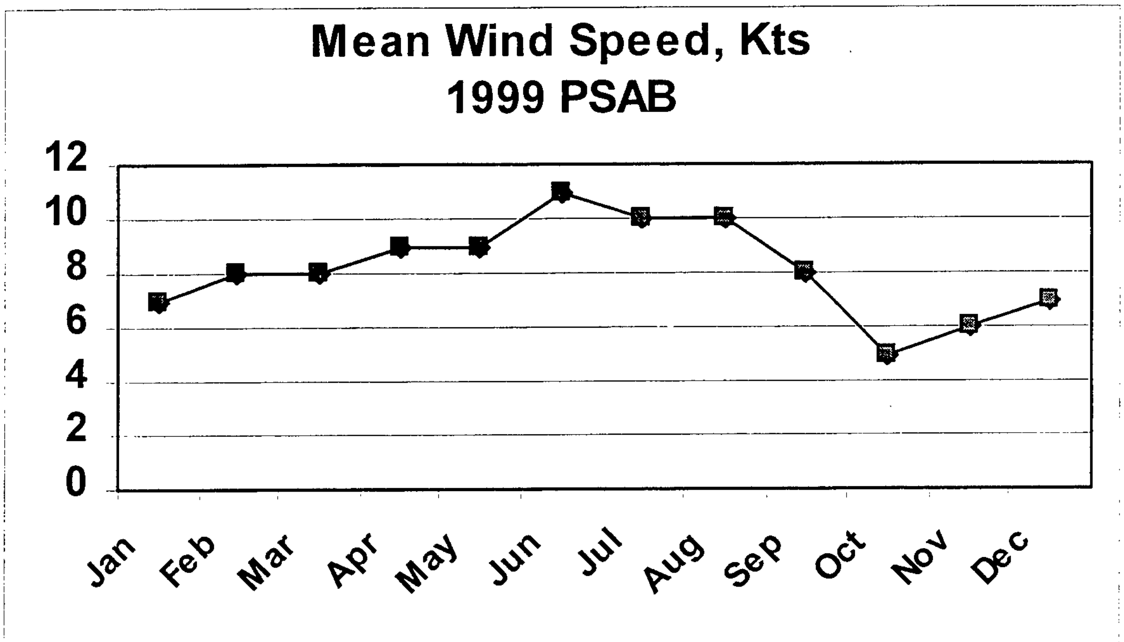
Table 7. PM-10 and TSP Data

PM10					TSP				
95 % UCL	**=**	**92.778 ug/m3**			**95 % UCL**	**=**	**268.991 ug/m3**		
CT	**=**	**81.486 ug/m3**			**CT**	**=**	**219.31 ug/m3**		
Range	**=**	**29**	**to**	**218.4**	**Range**	**=**	**39.6**	**to**	**612.5**
EPA Standards									
		Annual Average					Not to exceed more than once per year		
$PM_{2.5}$	=	15 ug/m3			24 hr $PM_{2.5}$	=	65 ug/m3		
PM_{10}	=	50 ug/m3			24 hr PM_{10}	=	150 ug/m3		

It is important to note that the EPA standards are based on protecting the health of susceptible populations – young, elderly, and individuals with illnesses (e.g. asthmatics and cardiopulmonary disease). Our deployed population should not fall into this category which suggests that our troops can be exposed to higher concentrations without adverse health effects.

The average concentration and range of PM_{10} is in excess of the EPA standards. In all, 4 days exceeded the 150 ug/m^3. However, when looking at Figure 5 (below), we would expect much higher concentrations during the summer months due to the higher winds. Similarly, of the 4 days that exceeded 150 ug/m^3, 3 of them were in December. In accordance with the EPA Guideline for Reporting of Daily Air Quality – Pollutant Standards Index (PSI), the air during this two month period ranges from "good" to "unhealthy" (excluding the one day over 200).

Figure 5. Mean Wind Speed



The associated health effects for a rating of "unhealthy" are *increased respiratory symptoms and aggravation of lung disease*. It is likely that during the summer months, the PSI will indicate hazardous conditions (above 301 ug/m3) which relate *to serious risk of respiratory symptoms and aggravation of lung disease*. The health effect from inhaling particulate matter varies depending on the particulate size. The particulate that ranges in size from 2.5 to 10 microns is defined as course fraction particles and particulate size less than 2.5 microns is defined as fine particles.

Coarse particles come from sources such as windblown dust from the desert, agricultural fields, and dust kicked up on paved roads from vehicle traffic. These particles can accumulate in the respiratory system and aggravate health problems such as asthma.

Fine particles are generally emitted from industrial and residential combustion and vehicle exhaust. Fine particles are also formed in the atmosphere during gaseous chemical transformation. The fine particles are more of a health threat due to the ability to enter the alveolar region of the lung.

Clearly, the PM_{10} data exceeds the USEPA standard, but the actual health impact is not clear. A summary review of the reported respiratory illnesses for the past three years indicate that during the summer months there are lower numbers of reported respiratory problems. This will require further review to determine the types of reported respiratory illnesses.

Air quality normally considers other data to assess the overall quality of the air. Most common air quality parameters include ozone, nitrogen dioxide, sulfur dioxide, lead, and carbon monoxide. Data was not presented for these parameters.

DISCUSSION

Data Quality and Sampling

The concern is whether the data quality and quantity sufficiently represents potential exposures. The data does not appear to be representative of the site for exposure duration of 2 years, and there is insufficient data for statistical confidence.

Environmental exposures are assessed with samples from vegetation, fish and wildlife, water, sediment, soil, and air. The actual samples collected will depend on the site being evaluated and the type of risk assessment being performed. For PSAB and other Southwest Asia risk assessments, the primary exposure pathways are water, soil, and air. All samples that are collected to assess risk to human health are typically collected based on a sampling strategy that documents the rationale for the sample locations and frequency of collection.

The data collected thus far for PSAB does not appear to follow a strategic plan. The data collection appears to be arbitrary and the analysis does not follow the requirements for performing a typical risk assessment. For example, PSAB has 6432 sample analytes to assess the environmental chemical risk at the site, but only 3763 analytes are actually reviewed because the remaining 2669 analytes do not have established RBCs. Sample collection dates do not indicate a plan was in place to collect samples during the different seasons. To better characterize the risk present at a deployed location, a strategic sampling plan must be adhered to. The plan should address the three primary exposure media, air, water, and soil, the analytes of concern for that site, and the frequency of sample collection.

Once representative data are collected, it must be compared to a standard. Many of the analytes that do not have established RBCs may have other standards (e.g. maximum contaminant levels) established by the DOD, USEPA, or other federal and state agencies. A total of 212 different analytes were not screened for this assessment (see Appendix D for complete list). A basic discussion of the different types of media is provided below.

Air Sampling Data

The Clean Air Act (CAA) is primarily concerned with 3 main pollutants: criteria pollutants, hazardous air pollutants (HAP), and ozone depleting chemicals (ODC). Criteria pollutants have established National Ambient Air Quality Standards (NAAQS). NAAQS include carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter (with aerodynamic diameter less than or equal to (<=) 10 microns and <= 2.5 microns), and sulfur oxides. Hazardous air pollutants include the 188 toxic compounds listed under section 112(b) of the Clean Air Act. Ozone depleting chemicals include Class I and II compounds listed in 40 CFR 82. Typically, the risk assessment processes for evaluating air contaminants look at chemical exposures similar to the HAP. Due to the unique nature of an Environmental Risk Assessment as defined by DODI 6490.3, this assessment is concerned with HAP and NAAQS contaminants.

The air sampling data for this risk assessment spans a 3-week period of time. Typically, air sampling should be accomplished quarterly to account for the variations in seasons, both in chemical usage and climatic conditions such as wind and temperature. During the 3-week period, 29 samples were collected and approximately each sample had 124 analytes identified for analysis. In total, there are

1007 analytical results (not including NAAQS data). Of the 124 different analytes, 33 of them do not have an established RBC which corresponds to 196 analytical results not being screened. For this reason, it is imperative for the sampling strategy to identify which contaminants need to be evaluated for a given site and identify alternative sources for standards for comparison.

Two contaminants, particulate matter with aerodynamic diameter less than or equal to 10 microns (PM_{10}) and total suspended particles, were also sampled at PSAB. The results for PM_{10} exceeded the US EPA guidelines, but the health impact is uncertain. Risk assessments use established risk numbers to calculate overall risk to exposed populations. NAAQS do not have established risk numbers for this purpose. There are also no established federal standards for the HAP, but RBC values do cover 444 different analytes.

Water Sampling Data

The Safe Drinking Water Act (SDWA) is the main federal law that ensures the quality of drinking water and has established standards for drinking water quality. As with most standards, the SDWA emphasizes sound science and risk-based standard setting. As long as a water system meets the SDWA, no further action should be necessary. The risk assessment process strictly reviews the RBC values and does not consider the SDWA standards.

Similar to the air data, the water sample data reflects that samples were not collected systematically (quarterly or seasonally). There were 49 potable water samples collected that screened for 359 different analytes and totaled 2571 analytical results. Of these results, only 1099 analytical results were screened for this assessment because the remaining 1472 analytical results (172 different) did not have a corresponding RBC. Likewise, there were 19 non-potable water samples collected that screened for 314 different analytes and totaled 1174 analytical results. Of these results, only 549 analytical results were screened for this assessment because the remaining 625 analytical results (159 different) did not have a corresponding RBC.

There are 434 different analytes with RBC values for water. The SDWA only lists 71 primary contaminants with established maximum contaminant levels, 8 other primary standards for virus and bacteria, and 15 secondary standards (11 of which have contaminant standards). At the very least, drinking water sampling strategy should address the SDWA contaminants and then target selected contaminants that are of concern for the deployed location. Contaminants without standards offer little value to a risk assessment, but may be beneficial to understanding the overall health risk.

Soil Sampling Data

Soil sampling is unique from air and water because there are not national standards other than clean-up values. In this respect, it only makes sense to monitor for the contaminants of concern for the deployed location. There are 417 different analytes for soil with RBC values. For this assessment, only 1304 soil sample analytes were screened of the 1680 analytes available (47 contaminants were not reviewed).

Exposure and Toxicity

The exposure pathways were not adequately defined and therefore there is a potential of not evaluating all completed pathways. Data was not provided about soil, crops, meat, milk, sediments, and recreational activities. All of these contribute to total exposure. Information about where the meats, milk, and vegetables are procured will determine the significance of this missing data.

It is important to understand that the toxicity values were established to protect the health of the most sensitive populations, for a 30 year exposure duration. This health risk assessment for a deployed location, was defined as being an adult population, mostly military, with the maximum duration of 2 years. As with most health impact, the toxicity of chemicals can be highly variable in individuals. Overall physical condition, chemical sensitivities, and diet all play a major role in physiological response to exposure. The risk generated by the toxicity values used is based on chronic long-term exposures. Ideally, subchronic values should have been applied, but were not available from the Region 3 RBC table used for this HRA. When enough data is available, another site-specific assessment can be accomplished to determine more realistic risks. Probabilistic risk assessments are the next step in the tiered risk assessment process. When there is sufficient data, probabilistic risk assessments are a useful tool for characterizing the uncertainties associated with the HRA.

Air Quality

The issue of airborne particulate exposures needs to be addressed further. A literature review should be accomplished to study potential increases in incidence of pulmonary/allergic disease at variable $PM_{10}/PM_{2.5}$ levels. The literature should include case studies for the area of concern (Saudi Arabia or other desert environments).

RECOMMENDATIONS

1. Establish minimum sample requirements for deployed locations and the process for which the data will be assessed. Guidelines are available as established in the DoD Overseas Environmental Baseline Guidance Document (OEBGD) and corresponding Final Governing Standards (FGS).

2. Develop a sampling strategy in concert with risk assessors.

3. Documentation of sampling conditions (e.g. location, wind direction, and speed) must be accomplished. All unusual events that may have occurred during the sample collection must be documented.

4. More environmental samples need to be collected to increase the statistical power and confidence. Ambient air and water samples should have a complete, continuous year of quarterly chemical analysis as a baseline. Further sampling will be dependent on the results of this sampling and theater sampling strategy. Location specific requirements can be based on intelligence reports, industrial operations, and professional judgement.

5. Collect particulate matter samples over a year time frame. Air quality personnel recommend 6 day intervals between sampling. Currently, PSAB personnel have initiated this sampling. The samples are being analyzed at CHPPM—Germany.

6. A literature review of particulate matter and the potential impact on health should be accomplished for SWA. The review should investigate data about non-resident populations.

7. Sample detection limits should be addressed prior to contracting with the laboratory for analysis. The RBC values are known, so the required detection limits can be easily established as the RBC or some value lower than the RBC.

8. Information on the population and industries surrounding PSAB (Al Kharj) need to be captured. Similarly, identification of the types of wastes being burned in the incinerator located on the Saudi-military side of PSAB. This will help determine if any unique sample analytes need to be included.

9. Identify sample data that exists outside of AFIERA, and data that may be miscoded for a given location. This data can be incorporated into future risk assessments and more accurately evaluate potential health risks. Reportedly, there is drinking water sample data for PSAB at CHPPM—Germany.

CONCLUSIONS

A HRA was completed for military personnel deployed to Prince Sultan Air Base (PSAB). USEPA Risk Assessment Guidance for Superfund (RAGS) was used as the framework for conducting this risk assessment. Although this guidance was written to address health risk associated with environmental restoration, the approach is valid to assess exposure, toxicity, and potential risks at deployed locations. This risk assessment evaluated both the carcinogenic and non-carcinogenic health risks to military and civilian adult personnel.

The sample data provided was limited with respect to representativeness of the site. The samples did not capture potential differences due to seasonal variation and there are very few sampling days for the 3 year period. All of the samples reviewed in this assessment were analyzed by AFIERA's Chemistry Division (AFIERA/SDC) or by their contract laboratories. Reportedly, there is data from PSAB at CHPPM– Germany. <u>All of the available data should be provided to a risk assessor prior to initiating future risk assessments</u>.

Exposure information was provided with the project guidance. When exposure information was not provided, assumptions were made based on USEPA literature, military references, and professional judgement.

In addition to the HRA, a cursory review of air particulate matter was accomplished. Particulate matter sample results are higher than the established national ambient air quality standards for the US. Although the particulate matter is high for the US standards, it is not necessarily high for the deployed region. <u>Further evaluation is needed to better assess the potential health impact</u>.

Environmental samples have been collected at PSAB since 1996. As part of the HRA all potential exposure pathways were evaluated by comparing sample results to the USEPA Region III RBCs (established standards). When an analytical result was identified as being above the RBC, it was identified as a chemical of potential concern (COPC). In total we identified 20 COPC, 8 from air samples, 5 from non-potable water, and 7 from potable water. Soil data was reviewed and did not have any analytes above the RBC screening values.

The HRA performed on the 20 COPC resulted with risk values that are within the acceptable range considered safe by the USEPA. These risk estimates are based on very conservative estimates of exposure and toxicity and are likely to overestimate the actual risk. Risk assessment guidance does not provide comparison standards for particulate matter. Although there are questions about the representativeness of the data, <u>the results of the HRA suggest that personnel assigned and/or deployed to Prince Sultan Air Base for up to 2 years should not have negative impact on their health due to the environment</u>.

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APPENDIX A

SUMMARY OF DATA

A summary of the data is presented in the following tables.

Human Health Risk Assessment Prince Sultan Air Base

Summary of PSAB Sample Results

Total Number of Results: **6432**

Total Number Exceeding RBC: **63**

Code	Type	Total	> RBC
EX	Air-Ambient	1007	42
GN	Grab - Water (Non-Potable)	1174	6
GP	Grab - Water (Potable)	2571	15
OS	Other - Soil	1680	0

Assumptions:

Adult Population (No Children or Elderly)	
Exposure Duration:	2 yrs
Water Consumption:	2 - 5 L
Body Weight:	70 kgs
Use other EPA Defaults	

Total Number of COPC Analytes: **156**

Total Number Exceeding RBC: **109**

A = Air P = Potable Water N = Non-potable Water

Num	CAS	COPC	Total	> RBC	Freq	Media	RBC	Unit	Max	95% UCL	CT	Best Fit	Unique Sampling Days	Inclusive Dates For Sample Collectioin
1	107028	Acrolein	4	4	100%	A	0.02	$\mu g/m^3$	5.7	2.466	1.5	N	1	10-Dec-96 - 10-Dec-96
2	71432	Benzene	11	11	100%	A	0.22	$\mu g/m^3$	4.2	2.193	1.248	L	3	26-Nov-96 - 10-Dec-96
3	50328	Benzo(a)pyrene	9	1	11%	A	0.002	$\mu g/m^3$	0.002	0.001	0.001	N	3	26-Nov-96 - 10-Dec-96
4	319857	beta-BHC	8	1	13%	A	0.0035	$\mu g/m^3$	0.0038	0.002	0.001	N	3	26-Nov-96 - 10-Dec-96
5	56235	Carbon Tetrachloride	11	11	100%	A	0.12	$\mu g/m^3$	1.2	0.869	0.684	N	3	26-Nov-96 - 10-Dec-96
6	67663	Chloroform	11	10	91%	A	0.07	$\mu g/m^3$	0.66	0.417	0.312	L	3	26-Nov-96 - 10-Dec-96
7	74873	Chloromethane	11	4	36%	A	1	$\mu g/m^3$	2.5	2.5	0.889	L	3	26-Nov-96 - 10-Dec-96
8	75092	Methylene Chloride	11	6	55%	A	3.8	$\mu g/m^3$	210	210	49.5	L	3	26-Nov-96 - 10-Dec-96
9	7440382	Arsenic	3	3	100%	N	0.04	µg/L	7.1	7.1	5.1	N	2	23 Oct 97 - 4-Aug-98
10	75274	Bromodichloromethane	3	3	100%	N	0.17	µg/L	41.5	41.5	14	L	2	23 Oct 97 - 4-Aug-98
11	75252	Bromoform	3	3	100%	N	2.3	µg/L	23.9	23.9	8.1	L	2	23 Oct 97 - 4-Aug-98
12	124481	Chlorodibromomethane	3	3	100%	N	0.13	µg/L	34.6	34.6	11.7	L	2	23 Oct 97 - 4-Aug-98
13	67663	Chloroform	3	3	100%	N	0.15	µg/L	347.4	347.4	116	L	2	23 Oct 97 - 4-Aug-98
14	75354	1,1-Dichloroethene	9	9	100%	P	0.04	µg/L	0.5	0.369	0.261	L	5	7-Feb-97 - 8-Aug-98
15	117817	Bis(2-ethylhexyl)phthalate	11	1	9%	P	4.8	µg/L	5.7	2.324	1.3	L	5	7-Feb-97 - 8-Aug-98
16	75274	Bromodichloromethane	9	9	100%	P	0.17	µg/L	20.9	13.088	2.53	N	5	7-Feb-97 - 8-Aug-98
17	75252	Bromoform	9	3	33%	P	2.3	µg/L	4.3	2.703	1.678	N	5	7-Feb-97 - 8-Aug-98
18	56235	Carbon Tetrachloride	9	8	89%	P	0.16	µg/L	0.8	0.696	0.317	L	5	7-Feb-97 - 8-Aug-98
19	124481	Chlorodibromomethane	9	9	100%	P	0.13	µg/L	10.7	6.873	1.67	L	5	7-Feb-97 - 8-Aug-98
20	67663	Chloroform	9	7	78%	P	0.15	µg/L	57	57	6.51	L	5	7-Feb-97 - 8-Aug-98

Summary of Cancer Risks and Noncancer Hazard Indices; 2 Liters Water ingested per Day				
	RME		CT	
Exposure Route	Cancer Risk 2 yrs	NonCancer Systemic Hazard Index HI	Cancer Risk 2 yrs	NonCancer Systemic Hazard Index HI
Adult: Drinking Water -- Ingestion, 2 Liters per Day	1.72E-06	3.07E-05	4.62E-07	6.04E-06
Adult: Drinking Water -- Showering, Inhalation	6.32E-05	2.92E-09	1.43E-06	2.79E-05
Adult: Drinking Water -- Showering, Dermal	1.92E-06	1.84E-05	6.70E-07	6.17E-06
Adult: Residential -- Ambient Air	4.15E-06	5.16E-02	1.53E-06	1.22E-02
Adult: Residential -- Soil -- Dermal				
Totals	**7.10E-05**	**5.17E-02**	**4.09E-06**	**1.22E-02**

Summary of Noncancer Hazard Indices		
	RME	CT
Exposure Route	NonCancer Systemic Hazard Index HI	NonCancer Systemic Hazard Index HI
Adult: Drinking Water -- Ingestion, 2 Liters per Day	3.07E-05	6.04E-06
Adult: Drinking Water -- Showering, Inhalation	2.92E-09	2.79E-05
Adult: Drinking Water -- Showering, Dermal	1.84E-05	6.17E-06
Adult: Residential -- Ambient Air	5.16E-02	1.22E-02
Adult: Residential -- Soil -- Dermal		
Totals	**5.17E-02**	**1.22E-02**

Summary of Cancer Risks; Ingesting 2 and 11.4 Liters of Drinking Water per Day				
	RME		CT	
Exposure Route	Cancer Risk 2 Liters/Day	Cancer Risk 11.4 Liters/Day	Cancer Risk 2 Liters/Day	Cancer Risk 11.4 Liters/Day
Adult: Drinking Water -- Ingestion, 2 & 5 Liters per Day	1.72E-06	9.78E-06	4.62E-07	2.63E-06
Adult: Drinking Water -- Showering, Inhalation	6.32E-05	6.32E-05	1.43E-06	1.43E-06
Adult: Drinking Water -- Showering, Dermal	1.92E-06	1.92E-06	6.70E-07	6.70E-07
Adult: Residential -- Ambient Air	4.15E-06	4.15E-06	1.53E-06	1.53E-06
Adult: Residential -- Soil -- Dermal				
Totals	**7.10E-05**	**7.90E-05**	**4.09E-06**	**6.27E-06**

Reference Doses and Carcinogenic Potency Slope Factors

~~Sources~~

I = IRIS

E = EPA-NCEA provisional value

H = HEAST

A = HEAST Alternate

W = Withdrawn from IRIS or

O = other

Contaminan	CAS	EPA Cancer Class	Oral RfDo mg/kg/d	Source of data	Oral Slope Factor CSFo kg·d/mg	Source of data	Inhalation RfDi mg/kg/d	Source of data	Inhalation Slope Factor CSFi kg·d/mg	Source of data
1,1-	75354	C	9.00E-	I	6.00E-	I			1.75E-	I
Acrolei	10702	C	2.00E-	H			5.70E-	I		
Arsenic	744038	A	3.00E-	I	1.50E+0	I			1.51E+0	I
Benzene	71432	A	3.00E-	E	2.90E-	I	1.70E-	E	2.90E-	I
Benzo(a)pyren	50328	B2			7.30E+0	I			3.10E+0	E
Beta-BHC	31985	C	1.80E+0	I			1.80E+0	I		
Bis(2-	11781	B2	2.00E-	I	1.40E-	I			1.40E-	E
Bromodichlorometha	75274	B2	2.00E-	I	6.20E-	I				
Bromofor	75252	B2	2.00E-	I	7.90E-	I			3.90E-	I
Carbon	56235	B2	7.00E-	I	1.30E-	I	5.71E-	E	5.30E-	I
Chlorodibromometha	12448	C	2.00E-	I	8.40E-	I				
Chlorofor	67663	B2	1.00E-	I	6.10E-	I	8.60E-	E	8.10E-	I
Chloromethan	74873	C			1.30E-	H			6.00E-	H
Methylene	75092	B2	6.00E-	I	7.50E-	I	8.60E-	H	1.65E-	I

APPENDIX B

RISK CALCULATION TABLES

The risk calculations used for this HRA are presented in the following tables.

Human Health Risk Assessment
Prince Sultan Air Base

Adult Resident Drinking Water Ingestion

Daily Dose (LADD or CDD) = (RME or CT Conc. x IR x EF x ED) / (BW x AT)
Carcinogenic risk = LADD x Slope Factor
Hazard Quotient = CDD / Reference Dose

Contaminant	RME Conc. mg/L	Lifetime Average Daily Dose mg/kg/d	Chronic Daily Dose mg/kg/d	Cancer Slope Factor CSFo kg·d/mg	Refernce Dose RfDo mg/kg/d	Lifetime Cancer Risk	Systemic Hazard Quotient
1,1-Dichloroethene	3.69E-04	3.01E-07	1.05E-05	6.00E-01	9.00E-03	1.81E-07	9.49E-08
Bis(2-ethylhexyl)phthalate	2.32E-03	1.89E-06	6.63E-05	1.40E-02	2.00E-02	2.65E-08	1.33E-06
Bromodichloromethane	1.31E-02	1.07E-05	3.74E-04	6.20E-02	2.00E-02	6.63E-07	7.48E-06
Bromoform	2.70E-03	2.21E-06	7.72E-05	7.90E-03	2.00E-02	1.74E-08	1.54E-06
Carbon Tetrachloride	6.96E-04	5.68E-07	1.99E-05	1.30E-01	7.00E-04	7.39E-08	1.39E-08
Chlorodibromomethane	6.87E-03	5.61E-06	1.96E-04	8.40E-02	2.00E-02	4.71E-07	3.93E-06
Chloroform	5.70E-02	4.65E-05	1.63E-03	6.10E-03	1.00E-02	2.84E-07	1.63E-05

Description	Units	Value	Rationale (Source)
RME Concentration	mg/L	listed	95% Upper Confidence Limit or Maximium Detect Value
Ingestion rate	L/d	2	Site Specific Parameter
Exposure frequency	d/y	365	Site Specific Parameter
Exposure duration	y	2	Site Specific Parameter
Body weight	kg	70	Adult body weight, Convention; (USEPA 1991)
Averaging time	d	25550	Carcinogenic effects; (USEPA 1989)
Averaging time	d	730	Noncarcinogenic effects; (USEPA 1989)

Contaminant	CT Conc. mg/L	Lifetime Average Daily Dose mg/kg/d	Chronic Daily Dose mg/kg/d	Cancer Slope Factor CSFo kg·d/mg	Refernce Dose RfDo mg/kg/d	Lifetime Cancer Risk	Systemic Hazard Quotient
1,1-Dichloroethene	2.61E-04	2.13E-07	7.46E-06	6.00E-01	9.00E-03	1.28E-07	6.71E-08
Bis(2-ethylhexyl)phthalate	1.30E-03	1.06E-06	3.71E-05	1.40E-02	2.00E-02	1.49E-08	7.43E-07
Bromodichloromethane	2.53E-03	2.07E-06	7.23E-05	6.20E-02	2.00E-02	1.28E-07	1.45E-06
Bromoform	1.68E-03	1.37E-06	4.79E-05	7.90E-03	2.00E-02	1.08E-08	9.59E-07
Carbon Tetrachloride	3.17E-04	2.59E-07	9.06E-06	1.30E-01	7.00E-04	3.36E-08	6.34E-09
Chlorodibromomethane	1.67E-03	1.36E-06	4.77E-05	8.40E-02	2.00E-02	1.15E-07	9.54E-07
Chloroform	6.51E-03	5.31E-06	1.86E-04	6.10E-03	1.00E-02	3.24E-08	1.86E-06

Adult Resident Showering Inhalation.

Daily Dose (LADD or CDD) = (RME or CT Conc. x IR x EF x ED) / (BW x AT)
Carcinogenic risk = LADD x Slope Factor
Hazard Quotient = CDD / Reference Dose

Contaminant	RME Avg. Air Conc. in Shower mg/m3	Lifetime Average Daily Dose mg/kg/d	Chronic Daily Dose mg/kg/d	Cancer Slope Factor	Refernce Dose	Lifetime Cancer Risk	Systemic Hazard Quotient
Bromodichloromethane	5.44E-01	4.44E-05	3.62E-09				
Bromoform	1.99E-01	1.62E-05	1.32E-09	3.90E+00		6.32E-05	
Chlorodibromomethane	3.75E-01	3.05E-05	2.49E-09				
Chloroform	5.41E+00	4.41E-04	3.60E-08	8.60E-05	8.10E-02	3.80E-08	2.92E-09
Arsenic				1.51E+01		0.00E+00	

Description	Units	Value	Rationale (Source)
RME Concentration	mg/L	listed	95% Upper Confidence Limit or Maximium Detect Value
Inhalation rate	m3/min	0.01389	Default (USEPA 1991)
Exposure frequency	d/y	350	Site Specific Parameter
Exposure duration	y	2	Site Specific Parameter
Body weight	kg	70	Adult body weight. Convention: (USEPA 1991)
Averaging time carc	d	25550	Carcinogenic effects: (USEPA 1989)
Averaging time ncarc	d	730	Noncarcinogenic effects: (USEPA 1989)
Shower duration	min/d	15	

Contaminant	CT Avg. Air Conc. in Shower mg/m3	Lifetime Average Daily Dose mg/kg/d	Chronic Daily Dose mg/kg/d	Cancer Slope Factor	Refernce Dose	Lifetime Cancer Risk	Systemic Hazard Quotient
Bromodichloromethane	1.84E-01	9.98E-07	3.49E-05				
Bromoform	6.73E-02	3.66E-07	1.28E-05	3.90E+00		1.43E-06	
Chlorodibromomethane	1.27E-01	6.89E-07	2.41E-05				
Chloroform	1.81E+00	9.82E-06	3.44E-04	8.60E-05	8.10E-02	8.45E-10	2.79E-05
Aresenic				1.51E+01		0.00E+00	

Adult Resident Drinking Water Dermal Contact

Daily Dose (LADD or CDD) = (RME or CT Conc. x SA x pK x ET x EF x ED x 1E-3 l/ml) / (BW x AT)

Carcinogenic risk = LADD x Slope Factor

Hazard Quotient = CDD / Reference Dose

Contaminant	RME Conc. mg/L	Dermal Permeab. Coeff. cm/h	Lifetime Average Daily Dose mg/kg/d	Chronic Daily Dose mg/kg/d	Cancer Slope Factor	Refernce Dose	Lifetime Cancer Risk	Systemic Hazard Quotient
Bromodichloromethane	4.15E-02	2.00E-02	2.57E-06	9.00E-05	6.00E-01	9.00E-03	1.54E-06	8.10E-07
Bromoform	2.39E-02	2.00E-02	1.48E-06	5.18E-05	1.40E-02	2.00E-02	2.07E-08	1.04E-06
Chlorodibromomethane	3.46E-02	2.00E-02	2.14E-06	7.50E-05	6.20E-02	2.00E-02	1.33E-07	1.50E-06
Chloroform	3.47E-01	2.00E-02	2.15E-05	7.53E-04	7.90E-03	2.00E-02	1.70E-07	1.51E-05
Arsenic	7.10E-03	2.00E-02	4.40E-07	1.54E-05	1.30E-01	7.00E-04	5.72E-08	1.08E-08

Description	Units	Value	Rationale (Source)
RME Concentration	mg/L	listed	95% Upper Confidence Limit or Maximium Detect Value
Dermal Perm Coeff	cm/h	listed	Table 5-8, Dermal Exposure Assessment (USEPA 1992)
Surface area	cm3	23000	Adult skin surface area, Convention: (USEPA 1991)
Exposure frequency	d/y	365	Site Specific Parameter
Exposure duration	y	2	Site Specific Parameter
Body weight	kg	70	Adult body weight, Convention: (USEPA 1991)
Averaging time carc	d	25550	Carcinogenic effects: (USEPA 1989)
Averaging time ncarc	d	730	Noncarcinogenic effects: (USEPA 1989)
Bath duration	h/d	0.33	(USEPA 1992)

Contaminant	CT Conc. mg/L	Dermal Permeab. Coeff. cm/h	Lifetime Average Daily Dose mg/kg/d	Chronic Daily Dose mg/kg/d	Cancer Slope Factor	Refernce Dose	Lifetime Cancer Risk	Systemic Hazard Quotient
Bromodichloromethane	1.40E-02	2.00E-02	8.67E-07	3.04E-05	6.00E-01	9.00E-03	5.20E-07	2.73E-07
Bromoform	8.10E-03	2.00E-02	5.02E-07	1.76E-05	1.40E-02	2.00E-02	7.03E-09	3.51E-07
Chlorodibromomethane	1.17E-02	2.00E-02	7.25E-07	2.54E-05	6.20E-02	2.00E-02	4.49E-08	5.07E-07
Chloroform	1.16E-01	2.00E-02	7.19E-06	2.52E-04	7.90E-03	2.00E-02	5.68E-08	5.03E-06
Aresenic	5.10E-03	2.00E-02	3.16E-07	1.11E-05	1.30E-01	7.00E-04	4.11E-08	7.74E-09

Adult Resident Ambient Air Inhalation.

Daily Dose (LADD or CDD) = (RME or CT Conc. x IR x EF x ED) / (BW x AT)
Carcinogenic risk = LADD x Slope Factor
Hazard Quotient = CDD / Reference Dose

Contaminant	RME Conc. mg/L	Lifetime Average Daily Dose mg/kg/d	Chronic Daily Dose mg/kg/d	Cancer Slope Factor CSFi kg·d/mg	Refernce Dose RfDi mg/kg/d	Lifetime Cancer Risk	Systemic Hazard Quotient
Acrolein	2.47E-03	2.01E-05	7.05E-04		5.70E-06		4.02E-09
Benzene	2.19E-03	1.79E-05	6.27E-04	2.90E-02	1.70E-03	5.19E-07	1.07E-06
Benzo(a)pyrene	1.00E-06	8.16E-09	2.86E-07	3.10E+00		2.53E-08	
Beta-BHC	2.00E-06	1.63E-08	5.71E-07		1.80E+00		1.03E-06
Carbon Tetrachloride	8.69E-04	7.09E-06	2.48E-04	5.30E-02	5.71E-04	3.76E-07	1.42E-07
Chloroform	4.17E-04	3.40E-06	1.19E-04	8.10E-02	8.60E-05	2.76E-07	1.02E-08
Choromethane	2.50E-03	2.04E-05	7.14E-04	6.00E-03		1.22E-07	
Methylene Chloride	2.10E-01	1.71E-03	6.00E-02	1.65E-03	8.60E-01	2.83E-06	5.16E-02

Description	Units	Value	Rationale (Source)
RME Concentration	*mg/L*		*95% Upper Confidence Limit or Maximium Detect Value*
Inhalation rate	*m3/d*	**20**	*Site Specific Parameter*
Exposure frequency	*d/y*	**365**	*Site Specific Parameter*
Exposure duration	*y*	**2**	*Site Specific Parameter*
Body weight	*kg*	**70**	*Adult body weight, Convention; (USEPA 1991)*
Averaging time carc.	*d*	**25550**	*Carcinogenic effects; (USEPA 1989)*
Averaging time ncarc.	*d*	**730**	*Noncarcinogenic effects; (USEPA 1989)*

Contaminant	CT Conc. mg/L	Lifetime Average Daily Dose mg/kg/d	Chronic Daily Dose mg/kg/d	Cancer Slope Factor CSFi kg·d/mg	Refernce Dose RfDi mg/kg/d	Lifetime Cancer Risk	Systemic Hazard Quotient
Acrolein	1.50E-03	1.22E-05	4.29E-04		5.70E-06		2.44E-09
Benzene	1.25E-03	1.02E-05	3.57E-04	2.90E-02	1.70E-03	2.95E-07	6.06E-07
Benzo(a)pyrene	1.00E-06	8.16E-09	2.86E-07	3.10E+00		2.53E-08	
Beta-BHC	1.00E-06	8.16E-09	2.86E-07		1.80E+00		5.14E-07
Carbon Tetrachloride	6.84E-04	5.58E-06	1.95E-04	5.30E-02	5.71E-04	2.96E-07	1.12E-07
Chloroform	3.12E-04	2.55E-06	8.91E-05	8.10E-02	8.60E-05	2.06E-07	7.67E-09
Choromethane	8.89E-04	7.26E-06	2.54E-04	6.00E-03		4.35E-08	
Methylene Chloride	4.95E-02	4.04E-04	1.41E-02	1.65E-03	8.60E-01	6.67E-07	1.22E-02

Adult Resident Showering -- Calculated Air Exposure Concentrations

Contaminant	RME Conc. mg/L	Mol. Wt. g/mol	Henry's Constant atm-m3/mol	Kl cm/h	Kg cm/h	Overall Trans. Coeff. KL cm/h	Temp-adj. Trans. Coeff. KaL cm/h	Conc. leaving H2O Cwd mg/l	VOC Gener. Rate S mg/m3-min	Air Conc. at Shower End mg/m3	Avg. Air Conc. in Shower mg/m3
Bromodichloromethane	4.15E-02	1.69E+02	2.41E-03	1.02E+01	9.80E+02	9.25E+00	1.24E+01	1.40E-02	9.68E-02	1.05E+00	5.44E-01
Bromoform	2.39E-02	2.53E+02	4.60E-04	8.34E+00	8.01E+02	5.41E+00	7.24E+00	5.12E-03	3.53E-02	3.84E-01	1.99E-01
Chlorodibromomethan	3.46E-02	2.08E+02	9.90E-04	9.19E+00	8.82E+02	7.34E+00	9.83E+00	9.67E-03	6.67E-02	7.25E-01	3.75E-01
Chloroform	3.47E-01	1.19E+02	4.60E-03	1.21E+01	1.16E+03	1.15E+01	1.54E+01	1.40E-01	9.63E-01	1.05E+01	5.41E+00
Arsenic	7.10E-03	7.49E+01									

Description	Units	Value	Rationale (Source)
L-phase t.c. CO2	cm/h	20	
G-phase t.c. H2O	cm/h	3000	
Water visc. at 20C	cp	1.002	
Water visc. at 45C	cp	0.596	
Shower temp	K	318	
Droplet diameter	mm	1	
Drop time	s	2	
Shower flow rate	L/min	20	
Shower stall volume	m3	2.9	
Shower duration	min	12	
Air exchange rate	min-1	0.0166667	(RANGE: .5 TO 1.5 PER HOUR)

Contaminant	CT Conc. mg/L	Mol. Wt. g/mol	Henry's Constant atm-m3/mol	Kl cm/h	Kg cm/h	Overall Trans. Coeff. KL cm/h	Temp-adj. Trans. Coeff. KaL cm/h	Conc. leaving H2O Cwd mg/l	VOC Gener. Rate S mg/m3-min	Air Conc. at Shower End mg/m3	Avg. Air Conc. in Shower mg/m3
Bromodichloromethane	1.40E-02	1.69E+02	2.41E-03	1.02E+01	9.80E+02	9.25E+00	1.24E+01	4.74E-03	3.27E-02	3.55E-01	1.84E-01
Bromoform	8.10E-03	2.53E+02	4.60E-04	8.34E+00	8.01E+02	5.41E+00	7.24E+00	1.74E-03	1.20E-02	1.30E-01	6.73E-02
Chlorodibromomethan	1.17E-02	2.08E+02	9.90E-04	9.19E+00	8.82E+02	7.34E+00	9.83E+00	3.27E-03	2.25E-02	2.45E-01	1.27E-01
Chloroform	1.16E-01	1.19E+02	4.60E-03	1.21E+01	1.16E+03	1.15E+01	1.54E+01	4.66E-02	3.22E-01	3.50E+00	1.81E+00
Aresenic	5.10E-03	7.49E+01									

APPENDIX C

STATISTICAL ANALYSIS DATA

A summary of the statistical analysis is presented in the following tables. The tables presented are representative of all the data sets used for this HRA. Complete data sets are available upon request to AFIERA.

Human Health Risk Assessment
Prince Sultan Air Base

W Test for Goodness of Fit (Shapiro and Wilk)

Contaminant of Concern: PM10

Regulatory Exposure Limit	
Units of recorded Data (e.g. ppm, mg/m3)	ug/m3
Number of Samples	50
Significance Level (α)	0.05

k =	25
d =	84213.7602
d (ln) =	11.3140
W =	0.9060
W(ln) =	1.0001

See Tab A7

Wp(α):	0.947

Rank r	Plotting Position r/(n+1)	Modified Plotting Position	Data (Xi) ug/m3	Xi - M	(Xi-M)^2	Modified Plotting for Yi	ln (Xi) Yi	Yi - M (ln)	(Yi-M)^2
Totals			4074.3	2.274E-13	84213.76	4	214.33271	2.665E-15	11.313967
1	0.020	1.961	29	-52.486	2754.7802	7.3673	3.3673	-0.919	0.845
2	0.039	3.922	29.1	-52.386	2744.293	7.3707	3.3707	-0.916	0.839
3	0.059	5.882	30	-51.486	2650.8082	7.4012	3.4012	-0.885	0.784
4	0.078	7.843	30.2	-51.286	2630.2538	7.4078	3.4078	-0.879	0.772
5	0.098	9.804	31.4	-50.086	2508.6074	7.4468	3.4468	-0.840	0.705
6	0.118	11.765	38.4	-43.086	1856.4034	7.6481	3.6481	-0.639	0.408
7	0.137	13.725	44	-37.486	1405.2002	7.7842	3.7842	-0.502	0.252
8	0.157	15.686	44.2	-37.286	1390.2458	7.7887	3.7887	-0.498	0.248
9	0.176	17.647	51.1	-30.386	923.308996	7.9338	3.9338	-0.353	0.125
10	0.196	19.608	52.8	-28.686	822.886596	7.9665	3.9665	-0.320	0.102
11	0.216	21.569	53	-28.486	811.452196	7.9703	4.0	-0.316	0.100
12	0.235	23.529	55.7	-25.786	664.917796	8.0200	4.0	-0.267	0.071
13	0.255	25.490	56.1	-25.386	644.448996	8.0271	4.0	-0.260	0.067
14	0.275	27.451	56.8	-24.686	609.398596	8.0395	4.0	-0.247	0.061
15	0.294	29.412	57.4	-24.086	580.135396	8.0500	4.1	-0.237	0.056
16	0.314	31.373	59.6	-21.886	478.997	8.0877	4.1	-0.199	0.040
17	0.333	33.333	63.7	-17.786	316.342	8.1542	4.2	-0.132	0.018
18	0.353	35.294	63.8	-17.686	312.79460	8.1558	4.2	-0.131	0.017
19	0.373	37.255	65	-16.486	271.78820	8.1744	4.2	-0.112	0.013
20	0.392	39.216	65.8	-15.686	246.05060	8.1866	4.2	-0.100	0.010
21	0.412	41.176	65.9	-15.586	242.92340	8.1881	4.2	-0.099	0.010
22	0.431	43.137	67.9	-13.586	184.57940	8.2180	4.2	-0.069	0.005
23	0.451	45.098	68.4	-13.086	171.24340	8.2254	4.2	-0.061	0.004
24	0.471	47.059	68.8	-12.686	160.93460	8.2312	4.2	-0.055	0.003
25	0.490	49.020	69.2	-12.286	150.94580	8.2370	4.2	-0.050	0.002
26	0.510	50.980	71.6	-9.886	97.73300	8.2711	4.3	-0.016	0.000
27	0.529	52.941	72.1	-9.386	88.09700	8.2781	4.3	-0.009	0.000
28	0.549	54.902	73.9	-7.586	57.54740	8.3027	4.3	0.016	0.000
29	0.569	56.863	76.6	-4.886	23.87300	8.3386	4.3	0.052	0.003
30	0.588	58.824	78.3	-3.186	10.15060	8.3605	4.4	0.074	0.005
31	0.608	60.784	80.3	-1.186	1.40660	8.3858	4.4	0.099	0.010
32	0.627	62.745	81.8	0.314	0.09860	8.4043	4.4	0.118	0.014
33	0.647	64.706	82.9	1.414	1.99940	8.4176	4.4	0.131	0.017
34	0.667	66.667	83.8	2.314	5.35460	8.4284	4.4	0.142	0.020
35	0.686	68.627	86.4	4.914	24.14740	8.4590	4.5	0.172	0.030
36	0.706	70.588	91.6	10.114	102.29300	8.5174	4.5	0.231	0.053
37	0.725	72.549	94.5	13.014	169.36420	8.5486	4.5	0.262	0.069
38	0.745	74.510	95	13.514	182.62820	8.5539	4.6	0.267	0.071

See Tab A6

a_1	0.3751
a_2	0.2574
a_3	0.2260
a_4	0.2032
a_5	0.1847
a_6	0.1691
a_7	0.1554
a_8	0.1430
a_9	0.1317
a_{10}	0.1212
a_{11}	0.1113
a_{12}	0.1020
a_{13}	0.0932
a_{14}	0.0846
a_{15}	0.0764
a_{16}	0.0685
a_{17}	0.0608
a_{18}	0.0532
a_{19}	0.0459
a_{20}	0.0386
a_{21}	0.0314
a_{22}	0.0244
a_{23}	0.0174
a_{24}	0.0104
a_{25}	0.0035

Descriptive Analysis	
Mean (M)	81.486
Standard Error	2419.850502
Median	70.4
Mode	#N/A
Standard Deviation	41.45658171
Sample Variance	1718.648167
Kurtosis	2.172762198
Skewness	1.407200932
Range	189.4
Minimum	29
Maximum	218.4
Sum	4074.3
Count	50
Confidence Level(95.0%)	0.367637082

P =	0.95
n =	50
Gamma = (g) =	0.95
z(gamma) =	1.645
z (P) =	1.645
k (g P, n) =	1.822
t (P,df) = (P,n-1) =	0.063
Xp =	171.155
X(gamma) =	171.155

a =	1 - (z(gam)^2/2(n-1))	0.972392435
b =	z(P)^2 - (z(gamma)^2/n)	2.7

	NORMAL Statistic Name	Xi	Yi	LOGNORMAL 1 / ln Yi	Statistic Name	
ug/m3	S = sample Std Dev =	41.457	0.481	1.62	= GS	[unitless]
ug/m3	Mean = M =	81.486	4.287	72.72	= GM	ug/m3
ug/m3	M - S = X (16%)	40.029	3.806	44.98	= GX (16%)	ug/m3
ug/m3	M + S = X (84%)	122.943	4.767	117.59	= GX (84%)	ug/m3
ug/m3	M - t x S / (n^.5) = LCL =	81.116	4.282	72.41	= GLCL	ug/m3
ug/m3	M + t x S / (n^.5) = UCL =	81.856	4.291	73.03	= GUCL	ug/m3
ug/m3	M + Zp (95%) x S = X (95%)	149.682	5.077	160.31	= GX (95%)	ug/m3
ug/m3	M + k x S = UTL =	157.040	5.162	174.58	= GUTL	ug/m3
ug/m3	OEL =	0	0	0	= OEL	ug/m3
ug/m3	Median = Me =	70.40	4.25			
ug/m3	(M - Me) / S =	0.267	0.068			

Smaller Test Statistic, (M-Me)/S, implies better distribution. Normal or Lognormal

For Normal Distribution, M = Me = Mo (mean = median = mode)

For Lognormal Distribution, mean = median = mode for [ln (data) in Nepers]

For Lognormal Distribution, Me of data = GM of data [in ppm or mg/m3 = ug/L]

Conclude best fit for data is Lognormally Distributed

Calculating the Concentration Term

(In accordance with EPA Supplemental Guidance to RAGS)

The concentration term has uncertainty associated with estimating the true average concentration at a site, therefore the 95 percent upper confidence limit (UCL) of the arithmetic mean should be used for this variable. Once calculated, this term will be used to calculate estimated intake.

Obviously, with more data points, the higher the accuracy of the true mean. It is also important to consider transforming the data to the natural log (ln). Since our data is already transformed when fitting the data, both UCLs are calculated for us below.

Calculating the UCL of the Arithmetic Mean For a Lognormal Distribution

$$UCL = e^{(m + 0.5\, s*2 + s\, H\, /\, (n - 1)-1)}$$

Where:

UCL	=	upper confidence Limit
e	=	constant (base of the natural log, equal to 2.718)
m	=	mean of the transformed data
s	=	standard deviation of the transformed data
H	=	H-Statistic (from table in tab H)
n	=	number of samples

m	=	4.29
s	=	0.48
H	=	1.866
n	=	50

95 % UCL = 92.77818999 ug/m3

Calculating the UCL of the Arithmetic Mean For a Normal Distribution

$$UCL = m + t\ (s\ /\ (n^{-1})$$

Where:

UCL	=	upper confidence Limit
m	=	mean of the untransformed data
s	=	standard deviation of the untransformed data
t	=	Student-t statistic (Calculated)
n	=	number of samples

m	=	81.49
s	=	41.46
t	=	1.68
n	=	50

95 % UCL = 91.315 ug/m3

PM10

Conclude the best fit is Lognormal – Recommend Using the 95% UCL for a Lognormal Distribution as shown below:

95 % UCL = 92.778 ug/ m3

* Note: The calculated 95% UCL is always the lowest value of the calculated value and max value.

W Test for Goodness of Fit (Shapiro and Wilk)

Contaminant of Concern: Chlorodibromomethane (CAS 124481)

Regulatory Exposure Limit	0.13
Units of recorded Data (e g ppm, mg/m3)	ug/L
Number of Samples	3
Significance Level (α)	0.05

k =	2
d =	786 615
d (ln) =	16.2042
W =	0.7500
W(ln) =	0.7500

See Tab A7

Wp(α):	0.767

Totals			35.1	0	786.615	2	0.771265	0	16.20424
Rank r	Plotting Position r/(n+1)	Modified Plotting Position	Data (Xi) ug/L	Xi - M	(Xi-M)^2	Modified Plotting for Yi	ln (Xi) Yi	Yi - M (ln)	(Yi-M)^2
1	0.250	25.000	0.25	-11.450	131.1025	0.6137	-1.3863	-1.643	2 701
2	0 500	50.000	0.25	-11.450	131.1025	0.6137	-1 3863	-1 643	2 701
3	0.750	75.000	34 8	22.900	524.41	5.5439	3 5439	3 287	10.803
4									
5									
6									
7									
8									
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32									
33									
34									
35									
36									

See Tab A6

a_1	0 7071
a_2	0.0000
a_3	
a_4	
a_5	
a_6	
a_7	
a_8	
a_9	
a_{10}	
a_{11}	
a_{12}	
a_{13}	
a_{14}	
a_{15}	
a_{16}	
a_{17}	
a_{18}	
a_{19}	
a_{20}	
a_{21}	
a_{22}	
a_{23}	
a_{24}	
a_{25}	

Descriptive Analysis		
Mean (M)		11.7
Standard Error	#DIV/0!	
Median		0 25
Mode		0 25
Standard Deviation		19.83198175
Sample Variance		393 3075
Kurtosis	#DIV/0!	
Skewness		1 732050808
Range		34 35
Minimum		0.25
Maximum		34.6
Sum		35.1
Count		3
Confidence Level(95 0%)		0.717986552

P =	0 95
n =	3
Gamma = (g) =	0 95
z(gamma) =	1.645
z (P) =	1.645
k (g, P, n) =	11 639
t (P,df) = (P,n-1) =	0.071
Xp =	31.165
X(gamma) =	31 165

a =	1 - (z(gam)^2/2(n-1))	0.323614652
b =	z(P)^2 - (z(gamma)^2/n)	1.8

	NORMAL			LOGNORMAL		
	Statistic Name	Xi	Yi	1 / ln Yi	Statistic Name	
ug/L	S = sample Std Dev =	19.832	2.846	17.23	= GS	[unitless]
ug/L	Mean = M =	11 700	0.257	1.29	= GM	ug/L
ug/L	M - S = X (16%) =	-8.132	-2.589	0.08	= GX (16%)	ug/L
ug/L	M + S = X (84%) =	31 532	3.104	22 28	= GX (84%)	ug/L
ug/L	M - t x S / (n^.5) = LCL =	10.889	0.141	1.15	= GLCL	ug/L
ug/L	M + t x S / (n^ 5) = UCL =	12 511	0.373	1.45	= GUCL	ug/L
ug/L	M + Zp (95%) x S = X (95%)	44.324	4.939	139.69	= GX (95%)	ug/L
ug/L	M + k x S = UTL =	242 533	33 388	###########	= GUTL	ug/L
ug/L	OEL =	0 13	0.13	0.13	= OEL	ug/L
ug/L	Median = Me =	0 25	-1 39			
ug/L	(M - Me) / S =	0 577	0.577			

Smaller Test Statistic, (M-Me)/S, implies better distribution: Normal or Lognormal

For Normal Distribution, M = Me = Mo (mean = median = mode)

For Lognormal Distribution, mean = median = mode for [ln (data) in Nepers]

For Lognormal Distribution, Me of data = GM of data [in ppm or mg/m3 = ug/L]

The data are the same for Normal and Lognormal Distributions

Calculating the Concentration Term
(In accordance with EPA Supplemental Guidance to RAGS)

The concentration term has uncertainty associated with estimating the true average concentration at a site, therefore the 95 percent upper confidence limit (UCL) of the arithmetic mean should be used for this variable. Once calculated, this term will be used to calculate estimated intake.

Obviously, with more data points, the higher the accuracy of the true mean. It is also important to consider transforming the data to the natural log (ln). Since our data is already transformed when fitting the data, both UCLs are calculated for us below.

Calculating the UCL of the Arithmetic Mean
For a Lognormal Distribution

$$UCL = e^{(m + 0.5\,s{*}2 + s\,H\,/\,(n-1)\text{-}1)}$$

Where:

UCL	=	upper confidence Limit
e	=	constant (base of the natural log, equal to 2.718)
m	=	mean of the transformed data
s	=	standard deviation of the transformed data
H	=	H-Statistic (from table in tab H)
n	=	number of samples

m	=	0.26
s	=	2.85
H	=	37.221
n	=	3

95 % UCL = 2.55049E+34 ug/L

Calculating the UCL of the Arithmetic Mean
For a Normal Distribution

$$UCL = m + t\ (s\ /\ (n^{-1})$$

Where:

UCL	=	upper confidence Limit
m	=	mean of the untransformed data
s	=	standard deviation of the untransformed data
t	=	Student-t statistic (Calculated)
n	=	number of samples

m	=	11.70
s	=	19.83
t	=	2.92
n	=	3

95 % UCL = 45.134 ug/L

Chlorodibromomethane (CAS: 124481)

The Data are the Same – Recommend Using the 95% UCL for a Lognormal Distribution as shown below:

95 % UCL = 34.600 ug/ L

* Note: The calculated 95% UCL is always the lowest value of the calculated value and max value.

W Test for Goodness of Fit (Shapiro and Wilk)

Contaminant of Concern: Benzene (CAS 71432)

Regulatory Exposure Limit	0.22
Units of recorded Data (e.g. ppm, mg/m3)	µg/m³
Number of Samples	11
Significance Level (α)	0.05

k =	6
d =	12.0659636
d (ln) =	5.1160
W =	0.7371
W(ln) =	0.9425

See Tab A7

Wp(α):	0.850

Totals			13.73	0	12.065964	1	-0.39238	0	5.1159995
Rank r	Plotting Position r/(n+1)	Modified Plotting Position	Data (Xi) mg/m3	Xi - M	(Xi-M)^2	Modified Plotting for Yi	ln (Xi) Yi	Yi - M (ln)	(Yi-M)^2
1	0.083	8.333	0.38	-0.868	0.75373967	0.0324	-0.9676	-0.932	0.868
2	0.167	16.667	0.38	-0.868	0.75373967	0.0324	-0.9676	-0.932	0.868
3	0.250	25.000	0.69	-0.558	0.31156694	0.6289	-0.3711	-0.335	0.112
4	0.333	33.333	0.69	-0.558	0.31156694	0.6289	-0.3711	-0.335	0.112
5	0.417	41.667	0.71	-0.538	0.28963967	0.6575	-0.3425	-0.307	0.094
6	0.500	50.000	0.78	-0.468	0.21919421	0.7515	-0.2485	-0.213	0.045
7	0.583	58.333	1.1	-0.148	0.02195785	1.0953	0.0953	0.131	0.017
8	0.667	66.667	1.2	-0.048	0.00232149	1.1823	0.1823	0.218	0.048
9	0.750	75.000	1.6	0.352	0.12377603	1.4700	0.4700	0.506	0.256
10	0.833	83.333	2	0.752	0.56523058	1.6931	0.6931	0.729	0.531
11	0.917	91.667	4.2	2.952	8.71323058	2.4351	1.4	1.471	2.163
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									
33									
34									
35									
36									

See Tab A6

a_1	0.5601
a_2	0.3315
a_3	0.2260
a_4	0.1429
a_5	0.0695
a_6	0.0000
a_7	
a_8	
a_9	
a_{10}	
a_{11}	
a_{12}	
a_{13}	
a_{14}	
a_{15}	
a_{16}	
a_{17}	
a_{18}	
a_{19}	
a_{20}	
a_{21}	
a_{22}	
a_{23}	
a_{24}	
a_{25}	

Descriptive Analysis	
Mean (M)	1.248181818
Standard Error	1.319318277
Median	0.78
Mode	0.38
Standard Deviation	1.098451803
Sample Variance	1.206596364
Kurtosis	5.620096944
Skewness	2.238078949
Range	3.82
Minimum	0.38
Maximum	4.2
Sum	13.73
Count	11
Confidence Level(95.0%)	0.020768039

P =	0.95
n =	11
Gamma = (g) =	0.95
z(gamma) =	1.645
z (P) =	1.645
k (g, P, n) =	2.571
t (P,df) = (P,n-1) =	0.064
Xp =	3.1
X(gamma) =	3.1

a =	1 - (z(gam)^2/2(n-1))	0.86472293
b =	z(P)^2 - (z(gamma)^2/n)	2.5

	NORMAL			LOGNORMAL		
	Statistic Name	Xi	Yi	1 / ln Yi	Statistic Name	
mg/m3	S = sample Std Dev =	1.098	0.715	2.04	= GS	[unitless]
mg/m3	Mean = M =	1.248	-0.036	0.96	= GM	mg/m3
mg/m3	M - S = X (16%)	0.150	-0.751	0.47	= GX (16%)	mg/m3
mg/m3	M + S = X (84%)	2.347	0.680	1.97	= GX (84%)	mg/m3
mg/m3	M - t x S / (n^.5) = LCL =	1.227	-0.050	0.95	= GLCL	mg/m3
mg/m3	M + t x S / (n^.5) = UCL =	1.269	-0.022	0.98	= GUCL	mg/m3
mg/m3	M + Zp (95%) x S = X (95%)	3.055	1.141	3.13	= GX (95%)	mg/m3
mg/m3	M + k x S = UTL =	4.073	1.804	6.07	= GUTL	mg/m3
mg/m3	OEL =	0.22	0.22	0.22	= OEL	mg/m3
mg/m3	Median = Me =	0.78	-0.25			
mg/m3	(M - Me) / S =	0.426	0.297			

Smaller Test Statistic, (M-Me)/S, implies better distribution. Normal or Lognormal

For Normal Distribution, M = Me = Mo (mean = median = mode)

For Lognormal Distribution, mean = median = mode for [ln (data) in Nepers]

For Lognormal Distribution, Me of data = GM of data [in ppm or mg/m3 = ug/L]

Conclude best fit for data is Lognormally Distributed

Calculating the Concentration Term

(In accordance with EPA Supplemental Guidance to RAGS)

The concentration term has uncertainty associated with estimating the true average concentration at a site, therefore the 95 percent upper confidence limit (UCL) of the arithmetic mean should be used for this variable. Once calculated, this term will be used to calculate estimated intake.

Obviously, with more data points, the higher the accuracy of the true mean. It is also important to consider transforming the data to the natural log (ln). Since our data is already transformed when fitting the data, both UCLs are calculated for us below.

Calculating the UCL of the Arithmetic Mean For a Lognormal Distribution

$$UCL = e^{(m + 0.5 s*2 + s H / (n - 1)-1)}$$

Where:

UCL	=	upper confidence Limit
e	=	constant (base of the natural log, equal to 2.718)
m	=	mean of the transformed data
s	=	standard deviation of the transformed data
H	=	H-Statistic (from table in tab H)
n	=	number of samples

m	=	-0.04
s	=	0.72
H	=	2.498
n	=	11

95 % UCL = 2.192958206 mg/m3

Calculating the UCL of the Arithmetic Mean For a Normal Distribution

$$UCL = m + t \ (s / (n^{-1})$$

Where:

UCL	=	upper confidence Limit
m	=	mean of the untransformed data
s	=	standard deviation of the untransformed data
t	=	Student-t statistic (Calculated)
n	=	number of samples

m	=	1.25
s	=	1.10
t	=	1.81
n	=	11

95 % UCL = 1.848 mg/m3

Benzene (CAS: 71432)

Conclude the best fit is Lognormal – Recommend Using the 95% UCL for a Lognormal Distribution as shown below:

95 % UCL = 2.193 mg/ m3

* Note: The calculated 95% UCL is always the lowest value of the calculated value and max value.

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APPENDIX D

SAMPLE ANALYTES WITHOUT RBC

A list of the sample analytes that were not reviewed is provided in this appendix.

Human Health Risk Assessment
Prince Sultan Air Base

List of Sample Analytes That Do Not Have an Associated RBC

Num	CAS	Chemical
1	51365	3,5-Dichlorobenzoic Acid
2	52686	Trichlorfon
3	52857	Famphur
4	55389	Fenthion (Baytex)
5	56495	3-Methylcholanthrene
6	56724	Coumaphos
7	57976	7,12-Dimethbenz(a)anthra
8	59507	p-Chloro-m-cresol
9	60117	p-Dimethylaminoazobenzen
10	60515	Dimethoate
11	62442	Phenacetin
12	64175	Ethyl Alcohol
13	67630	Isopropyl Alcohol
14	74884	Methyl Iodide
15	74975	Bromochloromethane
16	75569	Propylene Oxide
17	75650	tert-Butyl Alcohol
18	76017	Pentachloroethane
19	76142	Freon 114
20	78342	Dioxathion
21	78488	Butifos (Tribufos)
22	80568	a-Pinene
23	85018	Phenanthrene
24	86500	Azinphos Methyl(Guthion)
25	87616	1,2,3-Trichlorobenzene
26	87650	2,6-Dichlorophenol
27	88744	2-Nitroaniline
28	88755	2-Nitrophenol
29	90120	1-Methyl Naphthalene
30	90131	1-Chloronaphthalene
31	90153	1-Naphthol
32	91598	2-Naphthylamine
33	92671	4-Aminobiphenyl
34	96140	3-Methylpentane
35	97176	Dichlofenthion
36	99092	3-Nitroaniline
37	99309	Dichloran
38	99876	p-Cymene
39	100016	4-Nitroaniline
40	100754	n-Nitrosopiperidine
41	101053	Anilazine
42	101213	Chlorpropham
43	101553	4-Bromophenyl Phenyl Eth
44	106434	4-Chlorotoluene
45	107051	Allyl Chloride
46	107120	Propionitrile
47	107142	Chloroacetonitrile
48	107493	TEPP
49	108861	Bromobenzene
50	109068	2-Picoline (Synfuel)
51	110576	trans-1,4-Dichloro-2-but
52	111659	Octane
53	111706	1-Heptanol
54	111842	Nonane
55	111911	bis(2-chloroethoxy)metha
56	112403	n-Dodecane
57	113484	MGK 264
58	115071	Propene
59	115902	Fensulfothion
60	120365	Dichloroprop
61	122098	a,a-Dimethylphenethylam.
62	122145	Fenitrothion
63	123864	Butyl Acetate
64	124185	n-Decane
65	129679	Endothall
66	133904	Chloramben
67	134327	1-Naphthylamine
68	136458	MGK 326
69	139402	Propazine
70	141662	Dicrotophos
71	142289	1,3-Dichloropropane
72	143088	1-Nonanol
73	148798	Thiabendazole
74	150505	Merphos
75	191242	Benzo(ghi)perylene
76	208968	Acenaphthylene
77	224420	Dibenzo(a,j)acridine
78	297972	Thionazin
79	298022	Phorate
80	314409	Bromacil
81	319868	delta-BHC
82	327980	Trichloronate
83	470906	Chlorofenvinphos
84	513882	1,1-Dichloropropanone
85	563542	1,2-Dichloropropylene
86	563586	1,1-Dichloropropene
87	590207	2,2-Dichloropropane
88	622968	4-Ethyltoluene
89	624920	Dimethyldisulfide
90	732116	Phosmet
91	759944	EPTC
92	760050	5-Hydroxydicamba
93	786196	Carbofenothion
94	834128	Ametryn
95	886500	Terbutryn
96	950356	Methyl Paraoxon
97	957517	Diphenamid
98	959988	Endosulfan I
99	994229	Dyfonate
100	1014706	Simetryn
101	1031078	Endosulfan Sulfate
102	1066519	AMPA
103	1114712	Pebulate
104	1120214	n-Undecane

Num	CAS	Chemical	Num	CAS	Chemical
105	1134232	Cycloate	159	16655826	3-Hydroxycarbofuran
106	1194656	Dichlobenil	160	16752775	Methomyl
107	1332214	Asbestos	161	16984488	Fluoride
108	1480879	Sulfate	162	19902080	beta-Pinene
109	1563662	Carbofuran	163	21087649	Metribuzin
110	1582098	Trifluralin	164	21609905	Leptophos
111	1610179	Atraton	165	22248799	Stirofos
112	1646873	Aldicarb Sulfoxide	166	22781233	Bendiocarb (Ficam)
113	1688700	Chloride	167	23184669	Butachlor
114	1702176	Clopyralid	168	23950585	Pronamide
115	1861401	Benfluralin	169	25311711	Isofenphos
116	1897456	Chlorothalonil	170	26399360	Profluralin
117	1918021	Picloram	171	27314132	Norflurazon
118	1929777	Vernolate	172	33213659	Endosulfan II
119	2032657	Methiocarb	173	33245395	Fluchloralin
120	2051607	2-Chlorobiphenyl	174	34014181	Tebuthiuron
121	2104645	EPN	175	34643464	Tokuthion
122	2212671	Molinate	176	35400432	Bolstar
123	2437798	2244-Tetrachlorobiphenyl	177	36734197	Iprodione
124	2497065	Disulfoton Sulfone	178	39765805	trans-Nonachlor
125	2593159	Etridiazole	179	40186718	22334566-OctaCl biphenyl
126	2642719	Azinphos Ethyl	180	40487421	Pendimethalin
127	2675776	Chloroneb	181	41814782	Tricyclazole
128	3244904	Aspon	182	43121433	Triademefon
129	3689245	Sulfotepp	183	51877748	trans-Permethrin
130	4685147	Paraquat	184	52663715	2233446-HeptaCl biphenyl
131	5103719	alpha-Chlordane	185	53494705	Endrin Ketone
132	5103742	gamma-Chlordane	186	54774457	cis-Permethrin
133	5234684	Carboxin	187	55283686	Ethalfluralin
134	5836102	Chloropropylate	188	57837191	Metalaxyl
135	5902512	Terbacil	189	59756604	Fluridone
136	5915413	Terbuthylazine	190	60145224	224456-Hexachlorbiphenyl
137	5989275	d-Limonene	191	60168889	Fenarimol
138	6923224	Monocrotophos	192	60207901	Propiconazole
139	7005723	4-Chlorophenyl Phenyl Et	193	60233252	22346-Pentachlorbiphenyl
140	7421934	Endrin Aldehyde	194	62476599	Acifluorfen
141	7439921	Lead	195	66230044	Esfenvalerate
142	7439954	Magnesium	196	66441234	Fenoxyprop-Ethyl
143	7439976	Mercury	197	74223646	Metsulfuron-Methyl
144	7440097	Potassium	198	79241466	Fluazifop-butyl
145	7440235	Sodium	199	81777891	Clomazone
146	7440473	Chromium	200	108383C	m- and/or p-Xylene *
147	7440702	Calcium	201	57125F	Cyanide(Free) Amen to Cl
148	7700176	Crotoxyphos	202	ALKT	Alkalinity, (Total)
149	7786347	Mevinphos (Phosdrin)	203	COLOR	Color
150	8065483	Demeton	204	DCPAAM	DCPA Acid Metabolites
151	10061015	cis-1,3-Dichloropropene	205	DESETATR	Desethylatrazine
152	10061026	trans-1,3-Dichloropropen	206	DESIPATR	Desisopropylatrazine
153	13071799	Terbufos	207	HARDS	Hardness
154	13171216	Phosphamidon	208	MBAS	Surfactants (MBAS)
155	13194484	Ethoprop	209	NO2NO3	Nitrate/Nitrite - Total
156	15299997	Napropamide	210	RESF	Residue, Filterable(TDS)
157	15862074	2,4,5-Trichlorobiphenyl	211	RESNF	Residue, Nonfilter.(TSS)
158	16605917	2,3-Dichlorobiphenyl	212	TURB	Turbidity

DEPARTMENT OF THE AIR FORCE
711TH HUMAN PERFORMANCE WING (AFRL)
WRIGHT-PATTERSON AIR FORCE BASE OHIO

20 Mar 2017

MEMORANDUM FOR DTIC-CQ

FROM: 711 HPW/OMA (STINFO)
2510 Fifth Street, Suite W-415.09
Wright-Patterson AFB, OH 45433-7913

SUBJECT: Request to Change the Distribution Statement on a Technical Report

1. This memo documents the requirement for DTIC to change the distribution statement on the following technical report from Distribution Statement F to A, Approved for Public Release; distribution is unlimited.

AD Number: ADB263804
Publication Number: IERA-RS-BR-TR-2000-0007
Human Health Risk Assessment Prince Sultan Air Base, Saudi Arabia

Reason for request: A Freedom of Information (FOIA) request was submitted for access to this report. After thoroughly reviewing this report, a subject matter expert (SME) from the USAFSAM/OE organization found no information that would require the report to have any type of restrictive distribution. The SME subsequently authorized the distribution statement downgrade. My recommendation is to have the report status changed to Distribution A, Approved for public release: distribution unlimited.

2. Please feel free to contact my office at DSN 937-938-3367, or at carlos.pineiro.3@us.af.mil if you have any questions. Thank you.

Carlos Pineiro

CARLOS PINEIRO, DAF
711 HPW STINFO Officer